ARS CO-WY RESEARCH COUNCIL

1997 PROGRESS REPORTS

UNITED STATES DEPARTMENT OF AGRICULTURE

AGRICULTURAL RESEARCH SERVICE

NORTHERN PLAINS AREA

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INTRODUCTION

CO-WY RESEARCH COUNCIL

Natural Resource Research Progress Report

Gerald E. Schuman

The Research Units involved in Natural Resources Research are continuing their partnering that was developed under the Natural Resources Research Center in 1990 and officially disbanded in 1995. A Colorado-Wyoming Research Council was chartered by Dr. Will Blackburn, Area Director, Northern Plains Area, to promote and coordinate cooperative research activities among the CO-WY Council Research Units. The semi-formal structure of the Council facilitates communication and interaction among the Units, with the Northern Plains Area Director, and with our customers locally, regionally, nationally, and internationally. Leadership of the Council is accomplished through rotation among the Research Leaders. They have agreed that this compilation of research progress reports is of benefit to our customers and the continued positive responses we have received from them encourages us to continue its preparation. Most of the Units have also placed these reports or a facsimile of them on their individual Unit Web pages. These Web pages can be accessed through the NPA Home page at **www.npa.ars.usda.gov**.

The Units comprising the CO-WY Research Council are:

Soil-Plant-Nutrient Research	Fort Collins, CO
Sugarbeet Research	Fort Collins, CO
Great Plains Systems Research	Fort Collins, CO
Water Management Research	Fort Collins, CO
Central Plains Resource Management Research	Akron, CO
Rangeland Resources Research	Cheyenne, WY and Fort Collins, CO
National Seed Storage Laboratory	Fort Collins, CO
Arthropod-borne Animal Disease Research	Laramie, WY

This document includes reports of those Units doing research in the Natural Resources area. The report also includes 1-2 page documentation of mission, staff, research objectives, Web page addresses, telephone/fax numbers, and office addresses for the Sugarbeet Research, National Seed Storage Laboratory, and the Arthropod-borne Animal Disease Research Units.

ARS CO-WY Research Council Staff - 1997					
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PROGRESS REPORTS

CENTRAL PLAINS RESOURCES MANAGEMENT RESEARCH UNIT

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CRIS PROJECT

5407-12130-004-00 Dryland Cropping Systems to Improve Water and Nutrient Use Efficiency and Resource Protection

MISSION STATEMENT

To enhance the economic and environmental well-being of agriculture by development of integrated cropping systems and technologies for maximum utilization of soil and water resources. Emphasis is on efficient use of plant nutrients, pesticides, and water and soil conservation/preservation.

TECHNOLOGY TRANSFER

NRCS Soil Quality Team:

Transferred 1997 ARS fact sheets to NRCS Northern Plains Region State Offices.

Presented information on Soil Quality and Cropping Systems at the Western Kansas "Save the Soil" Conference, Norton KS.

Established soil quality teams in each of the seven states of their region. The local quality teams will enhance technology transfer to county field offices.

ARS Staff:

Sponsored a 90-Year Celebration for our Summer Field Day on June 17, 1997. Approximately 400 producers, agricultural business representatives, USDA-NRCS personnel, and CSU scientists attended.

Shared research results with USDA-NRCS by writing four fact sheets.

Served on the Board of Directors for the Colorado Conservation Tillage Association, and presented research results at their annual winter meeting.

Sponsored the Maximum Economic Yield (MEY) Club at Akron, where bi-monthly meetings are held each winter. Staff presented research data to producers.

Cooperated with the Eastern Colorado Range Station in integrating their cropping systems with livestock production.

Hosted tours for foreign visitors, explaining our cropping systems and research studies.

Presented research data on sunflower production at the National Sunflower Association Winter Workshop.

Presented research data at four regional CRP Management Seminars, held in eastern Colorado.

LONG TERM MONITORING AND ASSESSMENT OF SOIL PROPERTIES AND THE EFFECTS OF MANAGEMENT ON SOI L QUALITY

M. Sucik[1], J. Saunders[1] and M. Rosales[1]

PROBLEM: Agricultural practices in the past 100 years have had significant impacts on physical, chemical, and biological properties of soil. Organic matter levels in cultivated fields are often at one-half the level of native range sites for the same soil series. Fertilization with ammonia-based nitrogen has resulted in some cases of soil acidification. Soil compaction and water infiltration rates have also been altered by modern farming practices. In order for world food production to be increased or maintained, soil quality concerns need to be addressed and measured in order to determine whether present management conditions can sustain the soil resource at high productivity levels.

APPROACH: Soil quality indicators are monitored at benchmark locations using measurement techniques that are easy to use and provide immediate results. Field tests for infiltration rate, bulk density, pH, electrical conductivity, soil temperature, moisture content, nitrate nitrogen, microbial activity, etc. are conducted at these sites annually and results are compared to the benchmark measurement. This system can then help to evaluate the effects of management practices and whether present management will sustain the productivity of the soil resource. The sites are georeferenced using a global positioning system (GPS) and subsequent measurements are made at the same location and time of year to try to reduce spatial and temporal variability.

RESULTS: Measurements have been recorded for two years at Akron, CO. Several more years of data will need to be collected before trends in soil quality can be accurately identified. Comparisons between systems can be made however, and preliminary information indicates that organic matter levels are highest in native range and organic matter levels in CRP are higher than cultivated fields. It also appears that infiltration rates are faster under more diverse no-till cropping systems than conventional till wheat-fallow but slower than the rates for range and pasture. Bulk density measurements were collected in the surface three inches and we determined for future years that the data would be more meaningful if bulk density was collected below the plow layer or in the zone where density is highest.

FUTURE PLANS: Many more monitoring sites will be established in the next 2-3 years. The monitoring will continue indefinitely until we have a clear understanding of how management and rotations effect soil quality. It is hoped that eventually, individual farmers will implement their own monitoring system to help them maximize the efficiency of the soil resource.

[1] Soil Quality Assessment Team, NRCS, Akron, CO

SOIL QUALITY ASSESSMENT CARD

J. Saunders[1], M. Rosales[1] and M. Sucik[1]

PROBLEM: Farmers, conservationists, and other land mangers need methods to reliably and easily assess soil quality (SQ) so management decisions can be made that will ensure long-term productivity. Technology is needed to provide information about how land management affects soil quality. Land managers need SQ information which is relevant and focuses on SQ as an indicator of sustainable farming practices. The Natural Resource Conservation Service (NRCS) has for years implemented conservation programs from the top down. Voluntary conservation programs which offered one-on-one assistance on the farm from the NRCS have been shifted towards administrative office work. A grassroots approach to develop a farmer owned SQ assessment card was initiated as a pilot project in 1997. The SQ assessment card is a tool which can provide farmers a SQ record keeping system for their fields and provide an avenue of communication with conservationists and soil specialists about issues or problems related to SQ and soil management. The card represents a personal learning tool for assessing the impact of field management on SQ, thus educating the farmer and conservationist.

APPROACH: Groups of farmers (8-15) from a specific region are invited to a SQ card development meeting. The meeting is facilitated by agency personnel who do not steer the discussion, but allow farmers to develop their own ideas. Farmers are encouraged to look at sample soil profiles and discuss what SQ means to them. This activity is hands-on and is designed to generate discussion. Notes are taken and are displayed on flip chart paper. Farmers are then asked to identify 2-3 SQ indicators which they feel are important. Examples of indicators may be: soil tilth and structure, compaction, workability, water infiltration, plant vigor, soil organisms etc. Participants will define a poor, medium and good level of each selected indicator and write descriptions on cards. Participants vote to determine which indicators are most important. Following the voting process the farmers then choose what format and appearance the finished SQ card should have and what to name it.

RESULTS: There have been four farmer based SQ assessment card meetings to date. Most recently, eastern Montana and western North Dakota worked together to develop a mutual card. Cards have also been developed in New Mexico, Maryland and Oregon. Farmers who develop the card feel a sense of ownership. This type of methodology favors the exchange of ideas between conservationists and farmers which acts to bridge the gap between scientific, learned knowledge and indigenous knowledge that comes from life-long experience.

FUTURE PLANS: A national SQ assessment card team is working to design a users guide which will provide important information about each indicator including how and when to conduct the assessments. Marketing guidelines, pilot training sessions and field testing is planned for 1998.

[1] Soil Quality Assessment Team, NRCS, Akron, CO

FIELD DECOMPOSITION RATES AND SOIL COVER OF SURFACE CROP RESIDUES

R.M. Aiken, M.F. Vigil, G. Uhler and M. Shaffer[1]

PROBLEM: Surface crop residues reduce soil erosion and can improve soil water storage, conditioning the biological environment of crop seedlings and associated pests. Decomposition of surface residues alter these benefits and biological risks, and may compromise conservation compliance of dryland cropping systems. Knowledge of environmental factors altering decomposition rates can guide surface residue management.

APPROACH: Seasonal decomposition rates of surface crop residues (wheat, millet and corn) were measured under field conditions using litter bags, screen shelters and grab samples, collected at 1000 degree day intervals. Changes in biochemical composition of residues were sampled at initial, mid and final stages of field exposure. Accumulation of surface crop residues in various wheat, corn and millet crop sequences of the Alternative Crop Rotation study was determined pre-plant and post-harvest over four crop seasons. We quantified daily temperature effects on decomposition rates using a first order rate model, scaled to thermal time (cumulative degree days).

RESULTS: The number of standing stems decreased linearly over the fallow period (< 14 months). Loss of soil cover resulted from residue decomposition during warm and wet spring conditions, and was likely accelerated by mechanical action of wind during cold winter conditions. We observed similar decomposition rates among the crop residues. Fiber analysis appears to provide a means of quantifying nutrient pools within crop residues. The half-life of standing plus surface residues appears to be 5800 °C day, about 1.5 years of calendar time, while a shorter half-life for surface residues under wet soil conditions indicates more rapid decomposition.

FUTURE PLANS: A manuscript reporting results is in preparation.

[1]Great Plains Systems Research Unit, Ft. Collins, Colo.

SEASONAL RESIDUE IMPACTS ON RADIATIVE AND CONVECTIVE EXCHANGE PROCESSES

R.M. Aiken, D.C. Nielsen and L.R. Ahuja[1]

PROBLEM: The distribution of standing and flat surface crop residues condition the habitat of crop seedlings and associated pests. Cooler and wetter soils, associated with no-till crop management, alter decomposition rates of surface residues as well as soil quality factors impacting water management. Knowledge of residue effects on surface microclimate and subsequent processes can guide soil and water management.

APPROACH: We installed radiation, temperature, wind and soil water sensors in 10 m x 30 m plots of standing wheat, millet, corn and sunflower residues following harvest. Hourly data acquisition was screened for sensor reliability prior to archiving for subsequent analysis. Sheltering and insulating effects of crop residues are quantified as solar reflectance and wind velocity at 0.2 m relative to reference wind speeds at 2.0 m. Cover of flat residues and persistence of standing stems were sampled periodically. An energy balance simulation module of the Root Zone Water Quality Model quantified residue effects on evaporative demand.

RESULTS: Soil-residue systems differ in absorbed solar radiation, in relative windspeed at 0.2 m, and in near surface temperature dynamics. Simulation results indicate the shading and insulating effects of crop residues can reduce potential evaporation by 30 to 70%, relative to bare soil, under wet soil conditions. Effects of standing stems on light transmission and wind speed profiles can be quantified using light extinction and wind profile theory. Relationships derived for plant canopies can be adapted to standing stems, and are in qualitative agreement with observations.

FUTURE PLANS: A manuscript reporting results is near completion.

[1]Great Plains Systems Research Unit, Ft. Collins, Colo.

SURFACE CRUST FORMATION AND EFFECTS ON WATER, HEAT AND AIR TRANSPORT

R.M. Aiken, J.G. Benjamin, L.R. Ahuja[1] and G. Dunn[1]

PROBLEM: Surface soil crusts, formed by raindrop impact on exposed soil, restrict infiltration, soil aeration, and seedling emergence. Crusts can limit soil intake of water from intense rains of convective thunderstorms. Surface crusts limiting infiltration can reduce the quantity of water available for dryland cropping systems in the region; runoff associated with surface crusts can lead to soil loss as well. Previous studies indicate crust formation depends on rainfall intensity, soil characteristics (texture, cation composition, soil organic matter) and soil wetting conditions prior to rainstorm events.

APPROACH: We will use simulation models and rainfall simulators under controlled and field conditions to test the hypothesis that the settling depth of disaggregated and dispersed soil particles depends on rainfall intensity, relative to soil internal drainage capacity. We will use standard methods to measure surface soil strength and transport capacity of water, heat and air before and after crust formation. We will investigate use of micromorphologic methods to quantify crust properties. Soil properties known to affect crust formation will be determined for each experimental condition.

RESULTS: Nearly half the annual precipitation recorded at the Central Great Plains Research Station occurred in events exceeding 0.75", though these events comprised only 13% of annual events. Storms of this magnitude appear capable of inducing crust formation, while also exceeding the sorptive capacity of an initially dry 3" soil layer. Rainfall intensities ranged from 0.04 in./hr. to 3.19 in./hr with accumulations ranging from 0.08" to 0.91" during selected storm segments.

FUTURE PLANS: We are completing simulation of relative rainfall intensities on pore water velocities; the results will guide rainfall simulator studies to be conducted in the spring of 1998. Initial studies will be conducted under laboratory conditions using sieved soil packed into pans. Field studies will investigate either effects of cropping intensity or topsoil removal on crust formation. We are exploring collaborative work with Soil Microbial Systems Laboratory to relate aggregate strength to concentrations of the glycoprotein "glomalin", thought to derive from arbuscular mycorrhizal fungi.

[1]Great Plains Systems Research Unit, Ft. Collins, Colo.

SIMULATING YEAR-ROUND ENERGY AND WATER FLUX UNDER CROP RESIDUES

R.M. Aiken, G.N. Flerchinger[1], L.R. Ahuja, H.J. Farahani and K.W. Rojas

PROBLEM: Residue architecture (standing height, percentage soil cover, reflectance, etc.) modifies soil warming and water conservation by shading and 'insulating' surface soil layers. Decay of residue, dependent upon temperature and water conditions, results in seasonal changes in residue architecture, with impacts on soil temperature and water status. Accurate simulation of energy and water exchange processes provide analytic tools guiding residue management.

APPROACH: Crop residue impacts on energy and water exchange are quantified by PENFLUX, a soil-residue energy balance module providing boundary conditions for soil heat and potential evaporation modules of the Root Zone Water Quality Model (RZWQM). Year-round simulation of residue impacts by RZWQM is provided by incorporating energy exchange modules of SHAW, a process-level simulation model including freeze-thaw thermal dynamics of soil. Predictive accuracy of energy balance simulation is determined by comparing simulation results with micrometeorological observations acquired under dryland wheat, corn, sunflower and millet residues at the Alternative Crop Rotation experimental site.

RESULTS: Non-calibrated simulation of surface energy balance demonstrated high precision with persistent bias for net radiation ($R^2 > 0.99$) and surface temperature ($R^2 > 0.86$). Simulated evaporation, confirmed by soil water measurements, was greatest for systems with lowest residue cover--sunflower_NT and wheat_SM.

FUTURE PLANS: The PENFLUX module requires a companion residue water balance, under development, for accurate simulation of thermal conditions following precipitation/dew accumulation events. We will modify radiative and convective transport processes based on standing stem effects reported in this document. Further evaluation of RZ_SHAW and PENFLUX modules will utilize extensive micro-meteorological data acquired at Pullman, WA; Fort Collins, CO; and Akron, CO representing a range of residue architectures in semi-arid climates. Manuscripts reporting the predictive accuracy of these modules under winter and non-freezing conditions are in preparation.

[1]Northwest Watershed Research Center, Boise, Idaho

EVALUATION OF ALTERNATIVE CROP ROTATIONS TO WINTER WHEAT - FALLOW

M. Vigil, R. Aiken, J. Benjamin, D. Nielsen, R. Bowman and R. Anderson

PROBLEM: Producers in the Central Great Plains rotate winter wheat with fallow. Fallowing degrades soil by increasing loss of organic matter and organic nitrogen while exposing soil to wind and water erosion. Producers can counter this trend in soil degradation by cropping more frequently, yet producers in semiarid regions rely on fallow to stabilize their crop production. However, improved weed control methods during non-crop periods have increased precipitation storage efficiency, thus producers have more available soil water for crop growth. Also, new crop varieties are more efficient in converting water into grain, thus the need for fallow may be less than historically perceived. This study is evaluating crop rotations to increase cropping intensity and subsequently, reduce the amount of fallow.

APPROACH: A crop rotation study with 16 rotations was initiated in 1990 on a Weld silt loam at the Central Great Plains Research Station. Crops include: winter wheat, corn, sunflower, proso millet, foxtail millet, field pea, and triticales. With all rotations, we are minimizing tillage. Tillage is required to incorporate herbicides for sunflower. Three tillage systems, conventional-, reduced-, and no-till, are included in the wheat-fallow rotation as a basis for comparing soil quality changes. Standard agronomic practices for seeding rates, planting dates, varieties, and weed control are being followed.

RESULTS: During 1994-1997, W-C-M was the highest yielding rotation, yielding 110% more grain on a land area basis than conventional-till W-F. A W-W-C-M rotation has been established in the study, and we hope to improve yields with this rotation. In 1997, overall wheat yields were high, as extensive rain fell during heading. Yields approached 60 bu/ac with several rotations. Corn yields were the lowest since the study begin, with yields averaging < 15 bu/ac. Precipitation was very low during silking and tasseling. Proso yielded between 1500 and 1800 lb/ac for all rotations, and is the summer crop least affected by erratic precipitation. Sunflower was infested with stem weevils and phoma this year, leading to severe lodging and causing yields to average < 500 lb/ac. Sunflower yields with the M-S and W-S-F rotations have been low in all years of the study. Sunflower does not yield well if grown more than once every four years, due to phoma, a soil-born fungus. Our results suggest that a four year rotation of two winter crops followed by two summer crops is the most favorable for producers to maximize the rotation effect as well as control diseases and weeds. Initially, we had eight 2-yr rotations, but 7 of these rotations failed due to poor yields and excessive weeds. Only W-M has been successful, but its overall performance has not kept pace with W-C-M.

FUTURE PLANS: We are changing unsuccessful rotations into new 4-yr rotations: W-W-M-Pea and T-S-FM-Pea.

INTEGRATING CROPPING SYSTEMS WITH LIVESTOCK SYSTEMS

D. Schutz[1] and R.L. Anderson

PROBLEM: The Central Great Plains Resource Management Research Unit is exploring alternative cropping rotations, with the goal of increasing cropping intensity and consequently, cropping diversity. The CSU Eastern Colorado Research Center (ECRC) at Akron is exploring alternative feeds for effect on weight gain and overwintering of livestock. Inclusion of livestock in the overall production system not only increases potential use and markets for alternative crops, but also serves as drought insurance (poor grain crops could be turned into forage). The purpose of this team effort is to implement alternative cropping systems at ECRC for better utilization of crop aftermath and alternative forages while reducing annual cow costs.

APPROACH: We are implementing a study at the ECRC where we are comparing two systems: wheat - fallow versus triticales - foxtail millet - oat for hay. The forage system is being integrated with the cow-calf herd maintained on the ECRC station. We are still evaluating harvest efficiency of cattle grazing foxtail millet in swaths versus baling and feeding hay. Cattle were placed on the experimental site during the month of November, with daily weight gain and body condition score change being calculated. A second study is testing triticales for early spring grazing as an alternative feed source for cattle production. The studies are being conducted at both the ECRC station and the Central Great Plains Research Station.

RESULTS: For the systems study, extremely dry conditions at planting time for both foxtail millet and oat resulted in poor stands. Wheat established this fall is in good condition. Swathing foxtail in the fall and grazing swaths with cattle is more efficient than baling and hauling hay. The cattle graze the swaths without much feed loss. The main benefit is reduction of input costs. By using this technique, producers can extend their winter range feed supply. Triticales was grazed extensively by cattle in 1996. Because of the dry winter, most of the stand died in the spring. With normal conditions, triticales can be grazed for 45 days in the spring without affecting grain yield. Triticales begins spring growth earlier than either the winter range or winter wheat, and supplies high protein forage before the range grasses initiate growth. Cattle weight gain is greater when triticales is included for grazing compared to winter range alone.
Two fact sheets, oat for forage, and foxtail millet for forage, were published, summarizing results from the past three years. The fact sheets have been distributed to producers at our field days and winter meetings.

FUTURE PLANS: Our long-term objective is to develop integrated production systems for diversified farms that incorporate more intensive cropping with alternative cattle feeding programs. We will focus our future efforts on the systems study being conducted at the ECRC station.

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[1]Central Great Plains Research Station, Akron, Colo.

CROP HISTORY EFFECT ON WEED POPULATIONS IN SUMMER ANNUAL CROPS

R.L. Anderson

PROBLEM: Cropping patterns are changing in the Central Great Plains from wheat-fallow to more intensive crop rotations. One major contributing factor leading to this change in cropping is the replacement of tillage operations with herbicides for weed control.
However, public environmental concerns with the use of herbicides may limit or even eliminate future herbicide options. Secondly, several crops grown in this region do not have registered and effective herbicides for in-crop weed control. Because of these potential limitations, producers will need to use non-chemical weed control methods, including management practices that reduce weed seed production within the crop. Minimizing weed seed production in one crop may reduce weed populations in future crops, and subsequently reduce the need for herbicides.
The objectives of this study are: 1) determine the effect of cultural practices in winter wheat on weed populations in summer annual crops (oat for forage, corn, proso millet, and sunflower) planted the following year; and 2) rank crop response to wheat cultural systems in relation to weed population dynamics.

APPROACH: Three cultural systems are being compared: 1) Tam 107 at 675,000 seeds/acre planted in 12-inch rows, N at 60 lbs/ac applied in August before planting (conventional practices); 2) Lamar at 1 million seeds/ac planted in 12-inch rows, N applied in April before planting; and 3) Tam 107 at 1 million seeds/ac planted in 7-inch rows with N split-applied: 45 lbs in April + 15 lbs with wheat seed at planting. Weeds during fallow after wheat harvest were controlled by tillage or herbicides, resulting in split plots. Oat, corn, proso millet, and sunflower were planted in the spring of 1997.
Summer annual weeds: redroot pigweed, kochia, Russian thistle, witchgrass, and green foxtail, were seeded at 200 seeds/m^2 in designated sites after planting wheat. Weed populations were recorded weekly for the first nine weeks of the growing season of oat, corn, proso, and sunflower.

RESULTS: Data from 1996 and 1997 were similar, with weed populations being reduced 40 to 50% in corn, sunflower, or proso millet with system 2, if crops are established with no-till. Tilling the soil stimulates weed emergence 15 to 25%. The major weeds in all crops were green foxtail and redroot pigweed. Weed biomass was greatest in corn and least in proso.
With oat in 1997, the predominate weeds were kochia and Russian thistle. A dry spring inhibited winter annual grass seedling emergence. As in 1996, no-till favored the emergence of broadleaf weeds.

FUTURE PLANS: These strategies are being integrated into rotation schemes that control weeds with an ecological basis. Crop diversity will be included in managing weed populations.

CULTURAL SYSTEMS FOR WEED CONTROL IN SUMMER ANNUAL CROPS

R.L. Anderson and D.L. Tanaka[1]

PROBLEM: Producers are seeking production practices that reduce pesticide use for economic and environmental reasons. Cultural practices, such as narrow rows and increased plant populations, may enable producers to enhance crop competitiveness to weeds. For example, by reducing row spacing from 76 to 38 cm and doubling the planting population of corn, producers can reduce herbicide use in the Eastern U.S. by 75% without reducing weed control. These cultural practices also may work with summer annual crops in the Central Great Plains.
Research with cultural practices usually focuses on the effect of one or two practices on weed control, but does not evaluate systems based on several cultural practices in combination. This study is examining the impact of cultural practice systems on weed growth and interference in proso millet, corn, and sunflower. The ultimate goal is to develop a cultural system that will eliminate the need for herbicides or if needed, will favor reduced rates of herbicides.

APPROACH: Proso millet. We are comparing five cultural systems for proso tolerance of weeds. Components include: increased seeding rate, taller varieties, and delayed planting. In 1997, weed growth, and proso grain yields were determined from weed-free and weed-infested plots for each treatment.
Corn. Two cultural practices were compared, fertilizer placement and higher populations. N fertilizer was either broadcast or banded by the side of the planted row. Two populations were tested: 15,000 and 19,000 plants/acre. Each plot was split in two, with one half maintained weed free by herbicides and hand weeding. Green foxtail was broadcast in the other half and allowed to grow. Weed biomass was harvested 6 weeks after planting. Grain yield was determined for both weed treatments.

RESULTS: Proso millet. Compared to 1996, redroot pigweed emerged earlier in 1997. The conventional system of Sunup planted at 10 lb/ac on June 3 lost 25% of its yield to weeds. Cope planted at 15 lb/ac on the same date lost only 5% of its yield. Weeds were not competitive in later plantings of Cope and Sunup. Yields were similar for all systems except the conventional system with Sunup, which was severely stressed by drought. Its yield was 50% less than the other systems.
Corn. N placement (banding by the seed row) with the higher plant population (19,000) reduced weed biomass > 50% compared to N broadcast with 15,000 plants. This reduction in weed biomass improve grain yield by 25%, compared to the control.

FUTURE PLANS: Cultural systems in corn will be expanded to include narrow rows as well as N placement and higher plant populations. With sunflower, we will examine cultural systems that combine delayed planting, increased seeding rate, and narrow rows. The proso study will remain the same.

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[1] USDA-ARS, Mandan ND.

CULTURAL SYSTEMS FOR WHEAT PLANTED INTO WHEAT AND PROSO STUBBLE

R.L. Anderson

PROBLEM: Our rotation study suggests that a 4-yr rotation with two winter crops followed by two summer crops may be the most favorable for producers to maximize the rotation effect and control weeds. One promising rotation is W-W-C-M. The highest productive rotation currently in our rotation study is W-C-M. Thus, if producers use these two rotations, wheat will be planted into either proso or wheat stubble, with corn following the next year after wheat. Previous research at Akron has shown that cultural systems in wheat can reduce weed populations in future crops, suggesting that producers may be able to reduce herbicide input costs in continuous cropping. In addition, low crop residue levels of wheat in continuous cropping may reduce yields of corn, thus increased wheat biomass may improve rotation performance.
The objectives of this study is to develop cultural systems in wheat that favor wheat growth, and reduce the weed population in the following corn crop grown in sequence. The systems will be evaluated in both proso and wheat stubble, to supply data for management decisions related to continuous cropping.

APPROACH: Two varieties, Alliance and Lamar, have been planted with the hoe drill (12-in row spacing) and the JD 750 drill (7.5-in row spacing). Two nutrient management systems were applied: N broadcast vs band application. With the band system, P was banded with the wheat seed. Total N in both systems is 60 N lb/ac. The rate for P is 10 lb/ac. Planting rate is 650,000 seeds/acre.
The plots are being split for weed control, with green foxtail seed broadcast in one half of each plot. Foxtail populations will be assessed in the following corn crop in both stubble treatments.
Measurements in wheat: Stand counts will be assessed 3 weeks after emergence, with green foxtail and other weeds counted in early May. At maturity, yield and yield components for wheat will be determined. Crop residue levels will be measured after wheat harvest and at corn planting.
Measurements in corn: The split plots will be managed differently. The split plots with green foxtail will not be treated with herbicides. Green foxtail populations and biomass will be determined during the crop year. The weed-free plots will be treated with herbicides. Final grain yield of both treatments will be determined at maturity.

RESULTS: Wheat was planted in the fall of 1997. The wheat stubble had 2 more inches of soil water than the proso stubble. Stands were erratic in early October due to a dry September, but fall rains stimulated later emergence.

FUTURE PLANS: None at this time.

TILLAGE AND CROP ROTATION EFFECTS ON SOIL PHYSICAL PROPERTIES

J.G. Benjamin and C.A. Reule

PROBLEM: Twenty million acres of non-irrigated land in the Great Plains are farmed with clean-till wheat-fallow (W-F) rotation. Studies at the Central Great Plains Research Station (CGPRS) at Akron, Colorado, have shown that inserting summer annual crops such as corn, millet, or sunflower into the rotation leads to a beneficial rotation effect where wheat yields increase with more years between wheat crops (W-F<W-C-F<W-C-S-F). Speculation has attributed the rotation effect to many biological and physical phenomena ranging from better water use efficiency to a more favorable microbiological population. A cause for this effect could be an improved soil physical condition resulting from greater plant root activity (from the greater cropping intensity) or less destruction of soil structure and porosity (from the switch to fewer tillage operations). An improved soil physical condition could result in an increase of plant available water, less soil crusting, and better water infiltration. The objective of this study is to investigate changes in soil hydraulic properties, and subsequent changes in plant available water and water usage, caused by intensifying the crop rotation and decreasing tillage used for crop production.

APPROACH: An evaluation of soil hydraulic property changes caused by tillage and crop rotation was initiated in 1996. Samples were collected from the Alternative Crop Rotation (ACR) study at the Central Great Plains Research Station in Akron, CO. The rotations selected for study included: 1. wheat-fallow, conventional tillage (sweep plow 3 to 4 times during fallow); 2. wheat-fallow, no tillage; 2. wheat-corn-fallow, no tillage; 4. wheat-corn-sunflower-fallow, no tillage; and 5, wheat-corn-millet, no tillage. Field measurements of ponded infiltration rate, tension infiltration rates at -3 and -6 cm water head, and penetrometer resistance were taken in the spring of 1997 for comparison with samples taken in the fall of 1996. Soil cores were collected from the same plots for laboratory measurements of bulk density, saturated hydraulic conductivity, water diffusivity and water retention characteristics.

RESULTS: Wheel traffic had the major effect on soil physical properties. Infiltration was reduced in the wheel track from about 3.5 cm/h for the non-wheel-tracked zones to less than 0.5 cm/h in the wheel track in the fall of 1996. Infiltration increased in the spring of 1997 compared with fall of 1996, indicating some amelioration of traffic compaction over winter, but infiltration in the wheel track was still less than in the non wheel tracked zones. Similar soil hydraulic properties were found among all rotations, but there was an indication of greater saturated hydraulic conductivity at depths greater than 30 cm for rotations containing sunflower. Analysis continues on bulk density, pore size distribution and hydraulic conductivity for the spring, 1997 samples.

FUTURE PLANS: Further analysis of the observations should give indications of the effectiveness of the roots of different plant species for creating continuous pores and the subsequent effects on hydraulic conductivity and porosity. We will combine the analysis of soil hydraulic properties with yield information from these plots to help explain the rotation effect observed on these plots.

MANAGING SOIL COMPACTION TO ENHANCE CORN PRODUCTION AND SOIL BIOLOGICAL ACTIVITY

J.G. Benjamin, M.F. Vigil and D.C. Nielsen

PROBLEM: Sustainability of agriculture demands that soil resources remain productive. Degradation of soil resources is of particular interest in the Great Plains because relatively low soil organic matter levels make these soils very susceptible to many adverse soil management effects such as compaction. Most compaction research has addressed changes in soil physical characteristics, but less research has addressed the effects of these physical changes on plant productivity and biological activity. If we are to manage compaction in the same manner as we manage other crop production practices, we need information on the soil environment created by varying compaction levels and information on the compaction level tolerated by plants. The goals of this research fall within three broad categories: 1) Evaluate current concepts of soil mechanics as related to soil compaction; 2) Gain information about the soil environment and plant response to soil environmental changes caused by compaction to further understand the interaction between the soil and the plant; and 3) Test the effectiveness and longevity of methods to alleviate soil compaction.

APPROACH: We have established a study of soil compaction effects on corn (*Zea mays*, L.) growth and soil biological activity at Akron, Colorado, on a Weld silt loam (fine smectic, mesic Aridic Paleustolls). We included 3 levels of wheel traffic (0, 2, and 8 passes of a 7700 kg tractor) and 5 methods of compaction alleviation: 1) no alleviation from tillage; 2) shallow (20 cm deep) chisel plow tillage conducted only at the start of the experiment; 3) shallow chisel plow tillage conducted yearly during the experiment; 4) deep (45 cm deep) chisel plow tillage conducted only at the start of the experiment; and 5) deep chisel plow tillage conducted yearly during the experiment. We took soil samples before and after compaction in the fall to determine changes in the soil physical properties (bulk density, soil strength, infiltration, and water retention characteristics) caused by compaction. We will take soil samples in the spring to determine effects of compaction alleviation (winter freeze-thaw vs. tillage) on the same soil physical properties. The field will be planted to corn in the spring and plant growth characteristics will be measured throughout the growing season.

RESULTS: We are analyzing the soil samples collected in the fall of 1997. We expect to identify favorable and unfavorable soil environments for corn production, provide recommendations to producers on compaction management, and provide data for the inclusion of compaction in the continued development of models of the soil-plant-atmosphere system.

FUTURE PLANS: This experiment will run for the next three years. We will examine the long-term effects of soil compaction on crop productivity. We also hope to work with the NRCS Soil Quality Team to evaluate in-field soil quality indicators to determine soil compaction effects on soil quality.

METHOD DEVELOPMENT FOR EVALUATING AND QUANTIFYING SOIL QUALITY

R.A. Bowman, M. Sucik, M. Rosales and J. Saunders

PROBLEM: In the semiarid areas of the Great Plains, continued clean-till wheat-fallow cultivation of the native grasslands has resulted in significant losses of soil organic matter (SOM) because of wind erosion and decomposition. This loss of SOM results in a deterioration of soil quality and a reduction in crop productivity because of attendant losses in soil physical, chemical and biological properties such as rooting depth, water storage and soil aggregation. A need exists, therefore, to develop methodology to assess soil quality changes and direction of change. Our specific objective is to develop easy sensitive laboratory and field methods based on SOM content and other soil parameters to assess soil quality, and consequently, long-term soil productivity in croplands.

APPROACH: Our intent is to develop a quantitative index, which hopefully, will integrate losses in SOM due to erosion, decomposition, and nutrient uptake, and gains due to fertilization and net residue inputs and organic matter content from previous cropping. Besides measurement of SOM, labile organic C pools, enzyme activity, and other biologically based pools, bulk density (BD) and depth to lime (solum) are also measured. Thus, a Soil Quality Index (SQI) for new rotations other than wheat-fallow conventional-till is assessed based on SOM in the top 15 cm, the solum (kg organic carbon/m^2) or a predetermined depth (60 cm for Cumulative Organic Mater Index (COMI)). Additionally, a structural index (S_i) based on ratio of SOM % to clay % is also assessed to determine potential for degradation. Values for new crop rotations can then be compared to soils of the traditional wheat-fallow or with an adjacent native sod.

RESULTS: A new modified field method for SOM was developed and tested by the NRCS Soil Quality team with different soils in the Great Plains. This method is mostly used for screening purposes where differences of greater than 0.5% SOM are required. A fact sheet publication geared towards NRCS field personnel and progressive farmers has been published on this method. Of all the indices tried in the alternative cropping rotations, the COMI (Cumulative Organic Matter Index) is the easiest to determine since bulk density is not required. The particulate organic matter- carbon (POM-C) at the 0-2 inch depth appears to be well correlated to the quantity of crop residue and litter remaining after harvest. Generally, the various indices showed continuous cropping systems were retaining or increasing the SOM more than systems with fallow.

FUTURE PLANS: Future work is being planned closely with the NRCS Soil Quality Team. This team visits farmers and ranchers monthly across the Great Plains, and has a feel for the practical needs of producers. While there is a much greater interest in SOM now than 10 years ago, education emphasis is on longer reduced- or no-till rotations and less fallow to increase residue which will ultimately conserve more water, reduce erosion, and increase productivity. Field measurements for compaction, infiltration, presence of earthworms, pH, salts, and nitrates, in addition to SOM, will be conducted on selected farmers fields for direct comparison of W-F with longer rotations.

SOIL ORGANIC MATTER DYNAMICS UNDER ALTERNATE CROPPING AND TILLAGE SYSTEMS

R.A. Bowman, M.F. Vigil, R.L. Anderson, D.C. Nielsen, J.G. Benjamin and R.M. Aiken

PROBLEM: The conversion of Great Plains grassland to clean-till small grain farmlands since the mid 19th century has resulted in extensive loss of the native SOM because of wind erosion and decomposition. With 40% more organic carbon residing in the SOM than in the terrestrial plant biomass, it is easy to see how the conversion of grassland to wheat-fallow could create over time a drop in crop production and a significant increase in global CO_2. On the other hand, if we intensify the cropping system over the WF, and minimize soil disturbance through less tillage, and if we manage water, fertilizer, and pests efficiently, we should be able to reverse SOM loss and increase soil productivity. Our objective, therefore, was to evaluate different cropping systems for their efficiency in water and nutrient use, minimal soil erosion, minimal chemical leaching, and organic matter buildup. This report focuses on changes in SOM.

APPROACH: The study is located at Akron CO on a predominantly Weld silt loam. Three replications of 60 combinations and permutations of cropping and rotation sequences exist. Extensive sampling was conducted on all 180 sites for soluble (dichromate oxidation) and total SOM and POM and total organic C and N (C-N analyzer). Soil samples were collected at 0-2 inch, and at 2-6 inch depths for pH and nutrient stratification and for plow layer evaluations especially under the no-till conditions and mixing under conventional-till. Soil samples on different soil series were taken to 5 feet depth. Some measure of aggregate stability against wind erosion is assessed. Cumulative OM Index (COMI) and solum SOM will be assessed every 3 to 5 years.

RESULTS: Rotation plots were not assessed this year for COMI or solum SOM since it was believed that in this short time only the 0-2 and 0-6 inch depths would be influenced by residue and roots from rotation treatments. Three comparisons for SOM (cropping intensity, same length rotations, plots in 1993 versus same plots in 1997) all showed that increases were occurring primarily because of lack of fallow. Thus, there was always significantly less SOM in W-F plots than in continuous cropping plots (W-C-M). These differences also occurred for the total soil N and the soluble organic carbon. This soluble organic C is probably used by the microbes to degrade more resistant C from the residue, and also in the formation of stable aggregates. On a 6-inch basis, however, the C increases were not as large since very little C and N differences were found for the 2-6 inch depth.

FUTURE PLANS: Work on stabilization of new organic carbon from the residue and POM from different cropping intensities will continue by separating out the fines (clay and silt) from sand with POM. Lower depths will also be assessed for POM contribution from decomposing roots. A stability index (ratio of %SOM to %clay plus silt) which has presently been quantified on some CRP sites will also be assesses since this index could indicate the degree of stability of the soil where erosion could present a problem.

NUTRIENT, CEC, AND pH CHANGES UNDER ALTERNATE CROPPING SYSTEMS

R.A. Bowman and M.F. Vigil

PROBLEM: No-till systems usually conserve more moisture than clean-till systems, especially when weeds have been controlled. The extra available water invariably results in greater yield benefits from N and P fertilizer, with corn requiring more water and fertilizer than wheat. The role of water and nitrogen is being studied for efficient use. As cropping continues, other nutrients such as P and micronutrients which are seldom replenished, may become deficient. This need becomes even greater in the eroded areas of the Plains where P is chemically fixed by free lime, and where high P applications may also induce Zn and Fe deficiencies. The objectives of the research, therefore, are to evaluate nutrient availability and cycling under WF and alternate cropping systems where more residue is returned to the soil surface, and consequently, more P recycled from within the soil profile. Information is needed for P, S, and Zn use efficiency for subsequent crops such as corn and millet or oil crops or legumes after wheat in a reduced-till rotation.

APPROACH: In a Weld silt loam, various P parameters were measured at the 0-2 and 2-6 inch depths to assess P availability and cycling in selected plots from our alternate cropping and tillage system study (ACR). These parameters included available P pools such as those extracted by bicarbonate and anion-exchange resins, total soil P, and total soil organic P, residual P and phosphatase activity which is a measure of quickly available organic P. Available S and Zn were also evaluated in the surface 6 inches. Because of yearly N applications in continuous cropping systems, pH and CEC changes were also assessed. We also are assessing S levels because of our oil crops, and Zn because of corn.

RESULTS: Data from last year and this year clearly indicate more recycling of available P as we intensify the cropping system and produce more residue. Even though W-F treatments received fertilizer P every second year and longer rotations less often (only the wheat phase is fertilized with P), continuous cropping rotations still contained more available surface P. Similar to last year, Zn application showed no definable trend because of the nature of the small plots. This practice of fertilizing corn with Zn is becoming more routine in the Plains with starter fertilizer. Sulfur has not been applied to our oil crop plots in the ACR even though this could be warranted where SOM levels are less than 1.0% (some Rep 3 plots). Sulfur is studied independently in other field research by Vigil. Soil reaction (pH) is low with our continuous cropping rotations because of continuous N fertilization, but this does not seem to affect yields at this time. CEC has been negligibly changed..

FUTURE PLANS: We will continue to monitor nutrient data on ACR plots since we are only resupplying N and P. The Role of residue in buffering pH changes (cation production), and in resupplying the other nutrients are factors for future considerations. Vigil is looking at P and S needs in proso millet and oil crops. At this time, sunflowers seem to scavenge N and P very efficiently, with very little response from the fertility trials.

COMPARISON OF CRP LAND IN VARIOUS STAGES OF REST WITH WHEAT-FALLOW AND ADJACENT GRASSLAND

R.A. Bowman and R.L. Anderson

PROBLEM: Present Center projects relevent to CRP address soil and vegetation changes on small station plots. A principal question in this billion-dollar experiment is whether rested Cropland will be able to adequately support cropping again, and under what conditions or restraints this should be done. Obviously, if soil conditions are deemed inappropriate, a site could remain in grass. A main objective of this research, then, is to develop a set of criteria based on soil physical, chemical, and biological properties to determine adequacy for release of CRP lands back to cropping. An opportunity exists in Washington County to extend this field laboratory research to actual on-farm analysis of farmers' fields that have been in CRP for various lengths of time, the longest requiring three more years to complete its 10-year cycle. Data collected will reflect the true state of affairs and magnitude of change for these once fragile lands.

APPROACH: Six farms in Washington County in the Conservation Reserve Program were selected from data obtained through SCS. Two went into the program in 1986, two in 1988, and two in 1990. These farms were selected because they also had conventional wheat-fallow and native grassland sites nearby. Thus, one can simultaneously evaluate and compare changes under all three conditions. We also studied the take-out of CRP lands under different grass control systems to recrop. Soil parameters measured included: SOM, POM soluble organic carbon, TKN, available P, and pH. Soils were sampled at 0-5 and 5-15 cm with a minimum of three field replications with five composites.

RESULTS: Data from sampling in 1997 in high and low spots in the three different fields showed large variability for SOM content. While data showed mostly higher SOM concentrations for CRP sites compared to W-F sites, some W-F sites did have higher SOM content than comparable CRP sites. One of eight sites showed a higher SOM concentration for the CRP compared to the sod. Generally though, sod values were greater than both CRP and WF. Most of the increase from CRP sites came from the fine litter in the POM since fines (clay and silt without litter) recovered through screening from both sites did not vary significantly. There was about 5 percentage points more sand in the CRP sites than the WF sites, probably from more erosion in these more hilly CRP sites.

FUTURE PLANS: Data is presently being written up for publication on the six sites in 1986, 1988, and 1990. Collection of data from recent new breakout of brome CRP will continue. We will evaluate SOM changes on converting this CRP in brome back to a wheat-based cropping system. We will use no-till and reduced-till systems to preserve the gains attained during the 10-year rest period of CRP. While economics and conversion ease will be paramount, we will also be specifically looking to see which of these cropping systems will maintain or more slowly degrade the SOM acquired during the CRP rest period, thus improving the long-term productivity of that soil.

ORGANIC MATTER AND NUTRIENT CHANGES IN SIMULATED EROSION STUDIES

R.A. Bowman and M.F. Vigil

PROBLEM: Soil erosion is a serious problem in the Semiarid Plains. Its effects on water storage and nutrient availability have been extensively studied. Restoration with fertilizer or manures, and its effects over the long term are less well understood. Greb originally, and Smika later, conducted studies in the mid-50s with simulated erosion plots (different amounts of top soil removed) and added fertilizer. They removed from zero to 38 cm (15 inches) of top soil across the field. They were using added fertilizer to replace eroded topsoil in maintaining grain yields. We are presently revisiting these sites to evaluate long-term changes in selected chemical and physical properties (1956 vs 1996), and to assess presently, water use, crop yield and restoration potential of SOM with different N sources and sludge rates under more intensive and diverse cropping than the traditional wheat-fallow.

APPROACH: Nitrogen (ammonium nitrate), N and S (ammonium sulfate), and N, S, and micronutrients (sludge) were evaluated as they affected water use efficiency, and grain yields and residue production. Our first crop was sunflowers, but the site was previously in proso millet and corn and wheat. These previous crops (corn and millet) were adversely affected by the high pH (free lime) eroded soils and both showed less growth as the depth of top soil removed increased. We sampled the soil profile for water and nitrates, and the top 15 cm for SOM, S, and Fe and Zn. We hope to introduce green manures and legumes to rebuild the SOM , and the production potential of the soil. Because of the differences in top soil removed, soil and plant data are assessed separately for these top soil removed increments.

RESULTS: It appeared that broad-leaf crops such as sunflowers and prophy peas were less affected by the high pH calcareous soils (simulated erosion with 9 to 12 and 12 to 15 inches of top soil removed) than the grasses (corn and proso millet which showed significant reduction in yields). Prophy peas which were planted after sunflowers were not harvested so the residue and high N from the legume could be returned to the soil. No incorporation was done. Hopefully, the residue will also decrease erosion over the winter (an improvement over sunflower and fallow), and conserve more water for the next crop.

FUTURE PLANS: Green manure will be incorporated in the rotations to increase SOM and improve soil physical properties. Role of added N, S, and micronutrients from sludge will continue to be evaluated in the microplots where they were established.

AGRICULTURE AND BUSINESS MANAGEMENT ACTIVITIES IN NORTHEAST COLORADO

D.A. Kaan

COST OF PRODUCTION STUDIES: Cost of production studies have been completed for Northeastern Colorado and the Golden Plains Area counties this winter. These studies have been completed for dryland crops including winter wheat, corn, millet and sunflowers. Irrigated crops include winter wheat, corn, dry beans, alfalfa, potatoes and sugar beets. Data collection for these studies was achieved through individual surveys with producers throughout northeastern Colorado. Typical crop enterprises were defined for each crop based on the survey data collected. These cost of production studies will be published in the 1998 Golden Plains Area Agricultural Handbook.

RISK MANAGEMENT EDUCATION: The USDA Risk Management Agency kicked off an education initiative aimed at helping agricultural producers increase their knowledge and understanding of risk management principles in today's business environment. As we move towards full implementation of the 1996 FAIRA act and the resulting elimination of price supports in agriculture, producers' exposure to risk will increase. This education initiative focuses on an integrated approach to risk management. Five resource category areas have been defined and include production, marketing, financial, legal and human resources. An integrated management approach involves an understanding of each of these resources and the interrelationships that exist between them. The objective of this type of management is to create and take advantage of new opportunities to increase net revenue and owner's equity. Colorado State University Cooperative Extension is currently taking the lead in coordinating educational programming in the state of Colorado in integrated risk management principles and practices.

ECONOMIC INJURY LEVEL OF WINTER WHEAT TO RUSSIAN WHEAT APHIDS USING SUSCEPTIBLE AND RESISTANT VARIETIES

M. Koch

PROBLEM: The Russian wheat aphid (RWA) has damaged small grains in Colorado since March of 1986. Plant resistance to this insect has been considered the most cost effective means of limiting economic significance. Plant breeders have developed resistant wheat varieties that will compete with conventional varieties in respect to yield and test weight. This study is a side-by-side comparison of wheat varieties with and without the resistant genes to determine the yield potentials of the varieties with varied levels of aphid pressure.

APPROACH: Three hard red winter wheat varieties were used to test the RWA resistance level of the Dn4 gene. The varieties selected were TAM 107, Yuma and Lamar. The experiment was arranged in a split plot design. Plot size was six feet by six feet with the center two rows being the paired rows for analysis. One row was used for destructive sampling while the other was used for harvest data. The plots were infested with RWA using the bazooka method on March 19, 1997. The three infestation levels used were zero aphids with the seed treated with imidacloprid (Gaucho 480F), one-X rate, and a ten-X rate. The one-X rate was calibrated to be 23.2 RWA per row meter and the 10-X rate was 106.5 RWA per row meter.
Destructive sampling of one half of a meter began on April 21 (Zadoks 30-31). At this time, the tillers were showing symptoms and the RWA were beginning to reproduce rapidly. The total tiller counts were taken and broken down into four categories: no symptoms and no RWA, no symptoms with RWA, symptomatic with no RWA and symptomatic with aphids present. After the tiller counts were completed, the samples were immediately placed in Berlese funnels for 24 hours. The RWA were then counted from each sample. The second half of the sampling meter was collected on May 20 (Zadoks 49-58). Data was taken precisely as the first sample date. The growth stage varied considerably due to aphid pressure and a considerable drought period stressed the plants even further.

RESULTS: Harvesting of the experiment was completed on the twelfth of July. The row meter of heads was collected and counted. Thrashing began on the twenty-first of July. An Agriculex SPT-1 thrashing machine was used to separate the grain from the heads. Next, the samples were cleaned using a small Rapsco aspirator. Now the total seed weight was taken and the samples placed in a model 850-2 seed counter produced by The Old Mill Company. A sub-sample of one thousand seeds were taken and weighed to determine test weight. All data are being analyzed by Dr. Frank B. Peairs, Dpt of Bioagri. Sci. and Pest Mnge., CSU, Ft Collins, CO. Results will be published in the 1997 Colorado Field Crop Insect Manage. Res. and Demonstration Trials Tech. Bull. #TB98-5.

FUTURE PLANS: This experiment will be continued in 1998 using slightly different wheat lines. Comparisons will be made to TAM 107, TAM 107 R3 (which should be released in August), and two advanced lines containing Dn5 and Dn6 genes.

UNDERSTANDING AND MANAGING RUST AND STEM WEEVIL DAMAGE IN HIGH PLAINS SUNFLOWERS

M. Koch

PROBLEM: Research in the High Plains region has not focussed on sunflower rust as an economic problem. This study was to identify the rust races in this area and compare them with the races found in the Dakotas and Minnesota. Also, Spotted sunflower stem weevil (SSW) *Cylindrocopturus adspersus* (Leconte) were controlled to demonstrate the relative yield impacts from the two problems.

APPROACH: Plots located at the Central Great Plains Research Station were planted May 16 to maximize the stem weevil infestations. Carbofuran (Furadan 4F) was applied at planting using an FMC micro-injection unit at equal parts of water and chemical. The rate used was 0.75 lb AI per acre. Populations of this pest were 35 percent of the plants being infested with one or more stem weevils at the time of foliar treatment. Foliar treatments were applied for weevil control on June 30th. Esfenvalerate (Asana XL) at 0.05 lb AI per acre was applied using a four row, hand-held boom sprayer made by R & D Sprayers. A second application of Asana was applied on July 19 to ensure minimal SSW damage in plots.
The fungicides used for this study were applied on July 19 with less than 0.1 % of the leaf area showing rust. Four fungicides were used to control the rust. The chemicals and the rates used were: Tebuconazole (Folicur 3.6 F) at 4 oz/A, Propiconazole (Tilt) at 4 oz/A, Mancozeb (Dithane DF) at 2.0 lb. Product per acre, and Fenbuconazole (RH-7592 75WP) at 2.7 oz/acre. All treatments were applied with the hand-held boom.

RESULTS: Dr. Tom Gulya from the Northern Crop Science Lab in Fargo, ND visited the research site on August 25 and evaluated the rust part of this study. A second rust evaluation was conducted by Mike Koch on September 25 and the data was sent to Dr. Gulya. Dr. Larry Charlet, a colleague of Dr. Gulya, visited the plots on October 14 and lodging was analyzed. Stalks were later dug up and sent to the lab in Fargo. The stalks will be dissected and stem weevil larvae counts will be taken. A copy of the results will be available this spring. Preliminary analysis did not show different strains of rust in the High Plains region as compared to the Dakotas and Minnesota. The leaf area affected by rust was highly variable within each treatment. All indications this year point toward the SSW for being much more of an economic threat than rust.

FUTURE PLANS: This experiment will be conducted again for the 1998 growing season. The plot location will be moved to an irrigated site. By putting the plots under irrigation, rust spores will be generated at an increased rate. Thus ensuring adequate spore production for fungicide comparisons will be enhanced and give a more precise definition of the effects of the SSW and rust.

USING DEGREE-DAYS AS A MEANS FOR PREDICTING SUNFLOWER STEM WEEVIL EMERGENCE

J.S. Armstrong and M. Koch

PROBLEM: The study objective was to assist farmers in determining when to scout and treat for the Spotted sunflower stem weevil (SSW). Adult weevils emerge in the spring from one year old sunflower stalks. The adults then mate and begin laying eggs 7-10 days later. The economic threshold for adults is one per three plants. Due to this relatively low number, accurate weevil scouting is essential for economical control. SSW are difficult to scout for because they are small and tend to hide quite well. They will also drop off of the plant at the slightest disturbance and become nearly impossible to find once on the soil surface.

APPROACH: This was the final year of a three-year study. There were four cooperators in 1997 located in Hays, KS; St. Francis, KS; Scottsbluff, NE; and Akron, Colorado. Each cooperator was responsible for keeping an accurate record of daily maximum and minimum temperatures from January 1 and to monitor the cages for emerging weevils daily. All emerged weevils were collected and removed from the cages each day. A base temperature of 6 degrees and a maximum of 32 degrees Celsius were used for the degree-day accumulations. The formula used in the calculation was (max+min)/2-6.

RESULTS: General findings from the Akron site revealed the following information. Keep in mind the hot and dry weather pattern for the 1997 growing season. First emergence of the weevil in 1997 was on May 15. This was an average of sixteen days earlier than the other two years of this study. However, the accumulated growing degree days were much higher than the previous years. This pattern continued through the end of emergence which concluded on the seventeenth of June.
The 1997 data should further justify the need for producers to plant sunflower crops after the first of June. Stem weevil populations continue to threaten sunflower crops in the High Plains region. An accurate tool for predicting treatment of this pest will be very useful to producers and specialists of sunflowers. This study should provide the information necessary to minimize this pest's economic significance

FUTURE PLANS: Dr. J. S. Armstrong will be submitting this prediction model for journal publication in the near future. The results will be available upon request this spring.

CROP ROTATION AND TILLAGE EFFECTS ON WATER USE AND YIELD OF ALTERNATIVE CROP ROTATIONS FOR THE CENTRAL GREAT PLAINS

D.C. Nielsen, R.L. Anderson, R.M. Aiken, M.F. Vigil, R.A. Bowman and J.G. Benjamin

PROBLEM: Conservation tillage practices have made more soil moisture available for crop production in the central Great Plains, thereby providing greater opportunities for more intensive crop production. Information is needed regarding water use patterns, rooting depth, water use/yield relationships, precipitation storage and use efficiencies, and water stress effects of crops grown in proposed alternative rotations for the central Great Plains.

APPROACH: Six rotations [W-F(CT), W-C-F(RT), W-C-O(RT), W-SUN-F(RT), W-M-SUN-F(RT), W-SUN-M-PEA(RT)] are used for intensive measurements of water use and water stress effects on yield. (W:winter wheat, C:corn, F:fallow, M:proso millet, SUN:sunflower, PEA:pea CT:conventional till, RT:reduced till). Measurements include soil water content, plant height, leaf area index, grain yield, residue mass and cover, and precipitation.

RESULTS:

Rotation	Crop	ET (in)	Yield (lb/a)	Rotation	Crop	ET (in)	Yield (lb/a)
W-F(CT)	wheat	9.82	1897	W-C-O(RT)	corn	13.34	926
W-C-F(RT)	wheat	11.33	3329	W-C-F(RT)	corn	14.52	1530
W-C-O(RT)	wheat	8.45	1681	W-SUN-F(RT)	sunflower	10.86	76
W-SUN-F(RT)	wheat	9.87	2374	W-M-SUN-F(RT)	sunflower	13.13	765
W-M-SUN-F(RT)	wheat	9.27	547	W-SUN-M-PEA(RT)	sunflower	10.21	360
W-SUN-M-PEA(RT)	wheat	9.82	2229	W-M-SUN-F(RT)	millet	7.21	1454
W-SUN-M-PEA(RT)	pea	13.11	990	W-SUN-M-PEA(RT)	millet	6.27	485

INTERPRETATION: Generally the crop yields vs. ET follow relationships previously established, although winter wheat yields were about double what was expected. We cannot explain the high yields based upon timely precipitation. Corn yields were about half of what was expected, but this was due to very low precipitation during the last half of July and first half of August.

FUTURE PLANS: Water use, yield, rooting depth, height, leaf area, and growth stage measurements will continue to be made for as long as these rotations exist. Sunflower water use and yield data have been submitted for publication. Other rotation/water use dynamics data will be written up for publication this year.

DETERMINING BEST ADAPTED CULTIVARS AND OPTIMUM DRYLAND PLANT POPULATIONS FOR ALTERNATIVE CROPS

D.C. Nielsen

PROBLEM: Increased use of conservation tillage in the central Great Plains has increased precipitation storage efficiency and made more soil moisture available for crop production, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Future successful and profitable agricultural production will likely be improved with increased diversity of production. The objectives of this experiment were to determine best adapted cultivars and optimum plant populations for alternative crop species.

APPROACH: Potential adapted alternative crops are continuously being identified through contacts with other researchers conducting similar investigations in other areas of the country, and through literature review. During the 1997 growing season, four chickpea (garbanzo bean) cultivars (three kabuli and one desi type), and one lentil cultivar were evaluated, each at two seeding rates. The two seeding rates were higher and lower than recommended rates from other sources. Chickpea and lentil were planted on 4 April with a row spacing of 10". Plots were direct combined on 22 July (Myles) and 1 Aug (all others).

RESULTS:

Crop	Variety	Type	Planting rate lbs/acre	Yield lb/acre
Chickpea	UC5	Kabuli	164	629
Chickpea	UC27	Kabuli	136	631
Chickpea	Tammany	Kabuli	198	431
Chickpea	Sanford	Kabuli	149	374
Chickpea	Myles	Desi	82	826
Lentil	Brewer		205	57

INTERPRETATION: Higher planting rate resulted in higher yield for only UC5 and Tammany. All yields were much lower than in 1996 due to much lower growing season rain (9.28" in 1996; 6.30" in 1997). Very dry conditions following planting in 1997 also resulted in poor plant stands (only 0.35" in the three weeks following planting with no rainfall event greater than 0.10". Myles showed less of a decline from 1996 yield (approximately only 20% lower in 1997), substantiating observations that Desi-type chickpeas are more drought tolerant than Kabuli-type. The 1997 Kabuli-type variety yields were about 50% of the 1996 yields.

FUTURE PLANS: The experiment will be conducted similarly next year. We will begin looking at some amaranth varieties.

WATER USE, YIELD AND AGRONOMIC PRODUCTION OF ALTERNATIVE CROPS UNDER AN IRRIGATION GRADIENT

D.C. Nielsen

PROBLEM: Increased use of conservation tillage in the central Great Plains has increased precipitation storage efficiency and made more soil moisture available for crop prodcution, thereby providing greater opportunities for more intensive crop production as compared with convention wheat-fallow. Future successful and profitable agricultural production will likely be improved with increased diversity of production. Adding new crops to the traditional crops grown in this area will increase diversity. There are many unknowns associated with diversifying agricultural production with alternative crops, such as water requirements, water use-yield functions, rooting patterns, and water stress effects on plant growth, development, and yield.

APPROACH: Crops tested during the 1997 growing season were garbanzo beans (UC5, planted April 19), lentils (Brewer, planted April 19), pinto beans (Othello, planted June 6), and foxtail millet (Golden German, planted June 6). The plot area was under a solid set, gradient irrigation system. Plots were arranged such that there would be 4 replications of 4 levels of irrigation, with the highest irrigation level being weekly replacement of evapotranspirational losses and the lowest level being rainfed with no supplemental irrigation. Soil water measurements were made with a neutron probe. Water use was computed by the water balance method. Garbanzo beans were harvested on July 22 and 24. Lentils were harvested on July 30. Pinto beans were harvested on Sept. 4. Foxtail millet was harvested for forage on Sept. 3.

RESULTS: Problems with replacement of the irrigation system controller resulted in only three irrigations of the garbanzo beans and lentils resulting in a small ET range. Garbanzo bean yield ranged from 850 to 1450 lb/a over an ET range of 8 to 14 in. Lentil yield ranged from 700 to 850 lb/a over an ET range of 10 to 14 in. Pinto bean yield ranged from 1300 to 2500 lb/a over an ET range of 8 to 13.5 in. Foxtail millet yield ranged from 3100 to 7500 lb/a, but did not show a strong relationship to water use.

INTERPRETATION: Garbanzo beans and pinto beans may have a place as occasional entries into dryland rotations in this area.

FUTURE PLANS: Garbanzo bean, lentil, and pinto bean results will be submitted for publication. Work will continue with foxtail millet, profi pea, another garbanzo bean (desi type), and another dry bean class.

KENAF WATER USE AND PRODUCTION (FORAGE AND FIBER) UNDER A RANGE OF WATER AVAILABILITY

D.C. Nielsen

PROBLEM: Future successful and profitable agricultural production will likely be improved with increased diversity of production. Adding new crops to the traditional crops grown in this area will increase diversity. Kenaf is a potential alternative crop that has both fiber (paper, building materials, absorbants) and forage (livestock feed) uses.

APPROACH: Two experiments were conducted with kenaf (Everglades 41) A solid set, gradient irrigation area was planted May 9. Plots were arranged with 4 replications of 4 levels of irrigation (the highest irrigation level being weeklyreplacement of evapotranspirational losses and the lowest level being rainfed with no supplemental irrigation). In the second experiment kenaf was planted under a rainout shelter in May 12. Water treatments were 33, 67, 100, and 133% replacement of ET loss each week. Soil water measurements were made with a neutron probe. Water use was computed by the water balance method. One area of solid set kenaf was cut for forage on Aug. 14, allowed to regrow, and harvested again on Oct. 9. A sample of this first kenaf harvest was ensiled in mini-silos. A second area of kenaf grown for fiber grew from planting to Oct. 22. Rainout shelter kenaf was harvested for forage analysis on Aug. 7, and again on Oct. 10.

RESULTS: Forage production of kenaf was strongly related to water use. Total dry matter produced for the two solid set cuttings ranged from 1000 to 5500 lb/a over an ET range of 10 to 20 in. Total fiber yield of kenaf ranged from 1200 to 6400 lb/a over an ET range of 11 to 20 in. The 133% ET treatment appeared to suffer from lack of oxygen to the roots (yellow leaves, reduced dry matter production, low LAI). Forage characteristics are given in the following table.

Location	Cutting	% Crude Protein	% NDF	%ADF	Relative Feed Value
Gradient	1st	24-28	30-36	20-26	178-227
Gradient	2nd	16-24	25-34	17-23	196-286
Gradient	1st, Silage	21-25	29-38	22-28	164-238
Shelter	1st	26-29	33-40	27-34	146-194
Shelter	2nd	18-20	32-37	23-25	181-208

Crude protein and relative feed value tended to decrease with increasing water use. NDF and ADF tended to increase with increasing water use. Relative feed value is high.

INTERPRETATION: Kenaf produces a high quality forage, but low yields compared with corn silage and forage millet do not favor it for a dryland livestock forage in this area.

FUTURE PLANS: Both kenaf experiments will be repeated next year. Frequency of irrigation will be reduced in the rainout shelter to avoid the suspected water logging problem of 1997. Results will be presented at the Agronomy Society meetings and at the New Crops Symposium.

WIND SPEED PROFILES ABOVE AND WITHIN STANDING SUNFLOWER STALKS VARYING IN HEIGHT AND POPULATION

D.C. Nielsen and R.M. Aiken

PROBLEM: Sunflower could be a valuable new crop to be used in rotations with winter wheat in the central Great Plains. Concerns about wind erosion during the non-crop period following sunflower harvest arise from the assumption that low residue amounts provide inadequate protection for the soil surface. The objectives of this study were to measure the effects of standing sunflower silhouette area index (stalk height times diameter times population) on wind speed within and above standing sunflower stalks, and to compare the resultant changes in friction velocity ratio and erosion ratio for residue covered compared with bare soil surfaces.

APPROACH: Sunflower stalks were either laid flat after harvest or left standing at one of two heights. Stalk densities were variable, from approximately 10620 to 26140 stalks/a. Wind speed profiles within and above the standing stalks were measured with cup anemometers.

RESULTS: Friction velocity increased linearly with wind speed and increased quadratically with silhouette area index. Increasing silhouette area index increased the critical friction velocity ratio in a manner similar to previously reported wind tunnel results. Predicted reductions in wind erosion ratio based on these field-measured wind speeds are similar to values predicted from wind tunnel studies.

INTERPRETATION: Standing sunflower stalks have silhouette area index values that should reduce erosion potential to 0 to 12 % of that predicted for bare soils.

FUTURE PLANS: The results have been accepted for publication during 1998 in the Journal of Soil and Water Conservation. The effect of variation in sunflower silhouette area index on snow depth and overwinter soil water recharge have been analyzed and will soon be submitted for journal review.

INFLUENCE OF LEGUME GREEN-MANURE ON WINTER WHEAT YIELDS

M.F. Vigil, D.C. Nielsen and R.A. Bowman.

PROBLEM: With the exception of water, nitrogen (N) nutrition is the most important limiting input to profitable winter wheat production in the central Great Plains. Increases in N fertilizer costs have caused some farmers to consider alternative systems that include legumes as a source of N. Farmers need to know how these systems impact winter wheat yields and economic returns.

APPROACH: Two sites have been established in which the main plots consist of legume species: Austrian winter peas, spring field pea (cv. Profi), Hairy Vetch and a no-legume-summer-fallow plot fertilized at four N rates 0, 30, 60, and 90 lb N/ac. Within each main-plot, four sub strip plots are maintained which consist of four legume growth termination dates spaced two weeks apart. Soil water is measured in all legume plots and in the fallow plots at legume planting in April, at each legume-growth-termination event, at wheat planting and at wheat harvest to determine water used by the legume and the wheat. Above ground N and total legume biomass is determined at each termination date. Soil inorganic N is measured in each plot at each termination date in the top 2 feet of soil and at wheat planting time to monitor changes in available N. Following the legume fallow phase, wheat is planted and harvested using standard BMP's for dryland winter wheat.

RESULTS: We have three years of legume biomass data and 3 years of winter wheat yield data. Austrian Winter peas (AWP) have been the overall best performer as measured by biomass production (between 1500-3000 lbs biomass/acre) and total above ground N in plant tissue (50-130lbs N/acre). For the AWP we calculated a water-use efficiency of 335 lbs of dry matter per inch of water used on June 13, 1994. The 335 lbs of biomass contained 11.6 lb of N. In other words, 11.6 lbs of N was fixed or taken up by the legume for each inch of water use. The legumes used 5 inches of water (in addition to that amount lost in summer fallow) to produce 2400 lbs of dry matter. As soil water at wheat planting is reduced by previous legume crop water use, subsequent wheat yield is reduced by 7.5 bu/acre per inch. We measured reductions in wheat grain yields all three years. Eighty-eight percent of the variability in wheat yield loss could be described by a equation based on the previous year's legume water use (ET). At current fertilizer costs legume N is too expensive to be considered a reasonable alternative to chemical fertilizer in this system. In wet years the value of the forage ($80/ton) plus the wheat yield grown the subsequent year will bring higher net returns than wheat fallow. In a dry year the reverse is true and no legume should be grown during summer fallow.

FUTURE PLANS: We are continuing the experiment for another three seasons. We believe that 6 complete cycles of the system are needed to make a fair evaluation of potential changes in soil organic matter and mineralizable N. A refereed article is in review with Agronomy Journal.

NITROGEN MINERALIZATION FROM MANURES AND MUNICIPAL SEWAGE SLUDGE

M.F. Vigil, G. Smith, J. Davis and R.A. Bowman

PROBLEM: The disposal of animal waste and municipal sewage sludge from large population centers and concentrated animal feeding units is a national environmental concern. These materials, loaded with organic and inorganic nutrients, can be recycled in crop production systems as fertilizer and soil quality amendments. If managed properly, they become a resource instead of a waste product. However, the quantification of suitable rates of application, methods of application, crop response, and changes in soils after repeated application are data needed to adequately develop best management practices (BMP's) for these amendments.

APPROACH: The objectives of these experiments are to determine: the amount and rate of decomposition of organic amendments (manures and sewage sludge) in farm soils, as fertilizer and as soil quality amendments for crop production. Field studies are used to compare the N response of dryland crops (canola in 1995, sunflower 1996) to 4 tons of dry granulated sewage sludge with the N response to 30, 60, and 90 lb/ac of N as ammonium nitrate in 4-rep randomized complete block field experiments.
Lab studies are being conducted on 20 select animal manures representing 7 animal species. N mineralization (N_{min}) and C_{min} is being measured in manure amended Central Great Plains soils to develop first-order-decay-rate constants for these materials. Simultaneously we are evaluating computer models for their ability to predict how these amendments will impact soil nutrient availability and crop uptake.

RESULTS: Rates of N_{min} for 20 animal manures ranged from net immobilization (0 N_{min}) to 70% of the applied N being released after 132 days of incubation at optimum temperature and near optimal soil water contents.
We estimate from our lab studies that dry-granulated sewage sludge (5.3% N) applied at rates of 1.5 ton and 9 ton per acre will release (through microbial decomposition) 45 and 270 lbs of N in a given season under irrigated conditions in our region (about 28% of the total N applied). Under dryland conditions we may only see 34 to 200 lbs of N released for 1,5 and 9 tons of dry sludge. Less sludge N mineralization is expected on dryland because dryland soils are less biologically active then moist irrigated soils.

FUTURE PLANS: Lab studies are only in the beginning phases of research and will be continued. We are evaluating these products as an amendments to reclaim eroded soils. The Modeling effort is slowly moving along.

WHEAT RESIDUE DECOMPOSITION AS EFFECTED BY HERBICIDE AND UAN APPLICATION UNDER FIELD CONDITIONS

M.F. Vigil, M. Shaffer, R.L. Anderson and R.A. Bowman

PROBLEM: The amount and type of crop residues left on the soil after harvest affects soil erosion. For farmers to be in conservation compliance they must have, in accordance with their farm plan, a specified amount of residue cover at planting. Unfortunately, crop residues decompose after harvest and become less resilient during the non-cropped part of the season. These partially decomposed residues can then be wind blown and lost in the same manner as soil. Minimal quantitative information exists on the durability of standing crop residues as affected by the applications of herbicide and N fertilizer.

APPROACH: After wheat harvest (August of 1993, and 1994) 45 by 16 foot field plots were established with the following treatments where all rates are active ingredient/acre: 1) 0.5 lb Command + 0.5 lb Atrazine applied mid-August. 2) 0.5 lb Glyphosate + 0.25 lb Dicamba (Banvel) applications as needed. 3) 0.5 lb Paraquat + 1.0 lb Atrazine applied mid-August. 4) 0.5 lb Paraquat + 0.25 lb 2,4 D as needed. 5) no treatment, hand weeded (plastic spread over top of hand weeded area) and sprayed with 0.5 lb Command + 0.5 lb Atrazine. 6) tillage, no herbicide 2-3 times as needed (sweep plow with mulch treaders). Superimposed onto these treatments are three N regimes: no N applied, 30 lb N as UAN, and 60 lb N as UAN. All plots are replicated 3 times and arranged in a randomized complete block design. The following measurements are being taken. 1) Photo-documentation of plots was done after plots were established, after herbicide application, and then periodically as needed to document differences or lack of differences due to treatments. 2) The number of standing wheat stems is counted in select areas of each plot once a month during the no-snow months (depending on snow depth). Measurements continue until planting of the next wheat crop.

FINDINGS: This study has been completed. No increase in loss was measured from litter bag held residues or in standing stems from herbicide application after three years of measurement. Initially a color change is observed after herbicides and N solutions are applied. With time, color differences fade. The loss is primarily driven by the number of days with high winds, and optimal temperature and moisture for microbial activity. Herbicide treatments do not appear to have any direct effects on stem loss. Whereas, some indirect effects have been observed. We measured greater stem loss at the 60 lb N rate as compared to the 0 or 30 lb N rate. We found that the accumulated wind run was more highly correlated to the incremental loss of standing stem loss than either temperature or precipitation.

FUTURE PLANS: The experiment is complete. We are writing the first publication which primarily reports on the collected data. A second publication is forthcoming where in we are testing a simulation model.

PROFI PEAS IN A DRYLAND ANNUAL CROPPING STUDY

M.F. Vigil, C.A. Reule and A.D. Halvorson

PROBLEM: Conservation tillage has increased annual soil water storage. This has enabled the use of annual cropping for some soils of the central Great Plains. Annual cropping entails greater biomass production which increases the need for more intensive N fertilizer management. This study is designed to evaluate long term changes in soil C and N under annually cropped dryland conditions under different N fertility. Short term, the study allows for the estimation of N use efficiency and fertilizer N requirements of various dryland crops.

APPROACH: This is the 14th year of the dryland experiment, where the site has been cropped successfully with no fallow on a Weld silt loam soil. The site was in a barley-corn rotation until 1992 when oats for hay replaced spring barley. We have had two failures in the 14 years of cropping: winter wheat was grown in 1988 to replace a hailed out corn crop in 1987 and in 1990, poor stand and aphids limited barley yields to 21 bu/acre. The experiment is a 4-rep randomized complete block where the only treatment is N fertilizer rates of 0, 20, 40, 60, 80 or 120 lbN/acre. The study is managed with no-till to conserve water, and weed control has been through the use of contact and residual herbicides. Low rates of P have been applied with the seed at planting. Soil profile water and nitrates are monitored annually to determine N balance and water use efficiency. In general, this rotation and rotations in the region have been dominated by wheat, corn or millet. All of which are grass crops. Theoretically the inclusion of a broadleaf crop in rotations would have weed control benefits. This issue prompted the planting of profi yellow peas (a potential broadleaf grain legume) in the corn stubble on April 1, 1997. Rhizobial inoculated legumes have potential for fixing their own N so only a starter fertilizer containing 6.3 lbs of N and 30 lbs of P as P_2O_5 per acre (11-52-0) was applied at planting time. Weed control was attempted with 2 applications of Prowl. One application made in early March (1.5 pts /acre) and one made just prior to planting (2 pts/acre).

RESULTS: Through the years, the optimum N rate for the grain crops has been between 40 and 60 lbs N/acre for wheat and between 60 and 80 lbs for corn. A buildup of excess nitrate-N can be found in the soil of plots fertilized at 80 lbs or more.Triticale yields in 1995 were 5.5 ton/acre at an optimal N rate of 80 lb/acre. In 1996, maximum corn grain yields of 90 bu/acre were measured at the 120 lb N rate. At the 80 lb N rate 75 bu/acre of grain was harvested. In 1997, the unfertilized profi-pea crop got off to a slow start with a dryer than normal April. However, on 11, July 1997 we harvested 900 to 1100 lbs of grain with a whole plot average of 1011 lbs/acre. Prowl gave us minimal weed control in the peas.

FUTURE PLANS: We will continue this experiment for another 3 years to evaluate long term changes in soils under high N management and to determine changes in soil C and N with high productivity. We are considering the use of ^{15}N to evaluate fertilizer N recovery.

NITROGEN RESPONSE AND RESIDUE MANAGEMENT OF SUNFLOWERS IN A DRYLAND ROTATION

M.F. Vigil, R.M. Aiken and R.A. Bowman

PROBLEM: The current worldwide demand for edible oils has improved and somewhat stabilized the profitability of sunflowers in the Central Great Plains. However, knowledge of options for sunflower residue management and the fertilizer N response of this crop in the region is limited. Maintaining sunflower residues on the soil surface during fallow protects the soil from erosion, increases water infiltration and maximizes soil water storage. The objectives of these studies are: (i) to compare the loss of sunflower residues under no-till and reduce-till managed summer fallow, and (ii) to evaluate the nitrogen (N) use efficiency and plant derived N from fertilizer of this crop in a wheat-millet-sunflower-fallow rotation.

APPROACH: *In the sunflower residue study*: The disappearance of sunflower residue from sunflowers cut at two stalk heights (20 and 27 inches) were compared under no-till and reduce-till managed fallow in a 4-rep randomized complete block designed experiment. Weeds were controlled using a sweep-plow in the reduce-till plots. Glyphosate (Roundup) was used to control weeds in no-till plots. Standing-stem counts, percent-residue cover (line transect method) and surface-residue mass were measured during summer fallow on a monthly basis. *In the N fertilizer-rotation study*: Sunflower were planted and fertilized in a randomized split-plot 4-rep experiment. Main plots consist of rotation crop/phase (sunflowers, proso-millet, wheat or fallow) and sub-plots are fertilizer N rates of 0, 30, 60, or 90 lbN/acre. All phases of the rotation appear every year in each replication. Soil water and inorganic N are monitored at planting and after harvest to assess water and N use efficiency and to evaluate deep N and water extraction by sunflowers. Deep placed ^{15}N labeled N is being used to evaluate fertilizer N recovery with soil depth.

RESULTS: After three seasons no sunflower response to N has been measured. Sunflower grain yields have averaged near 1000 lbs over the three years regardless of fertilizer application rate. That is somewhat surprising because the 0 (check) fertilizer plots have not received N fertilizer for three years. We have measured deep removal of inorganic N at the 5 foot depth. But still have not measured a yield response. In 1995, Taller sunflowers (27 inch) fell over sooner then shorter sunflowers (20 inch). No-till resulted in 2950 lbs of residue mass per acre on the soil surface at wheat planting time and maintained greater then 35% residue cover during summer fallow. Sweep-plow managed fallow contained 1700 lbs of sunflower residue per acre at wheat planting time, but only 23% residue cover as measured by the line transect method. In 1996, the apparent advantage of no-till with respect to maintaining surface residue cover was much less and by the end of June, both no-till and conventional till managed summer fallow maintained less then 30% residue cover.

FUTURE PLANS: For both studies only two years of data has been collected. The N response of sunflowers in a rotation requires at least 2 complete cycles of the rotation for long term conclusions.

SOIL CARBON AND NITROGEN CHANGES IN A LONG TERM TILLAGE STUDY

M.F. Vigil, C.A. Reule, R.L. Anderson and R.A. Bowman

PROBLEM: Winter wheat-fallow is still the dominant cropping system in the Central Great Plains region of the United States. During fallow, weeds are generally controlled using sweep-plow tillage (stubble mulch). Weed control with herbicide chemistries currently available is generally too expensive to adopt unless a more intensive rotation is adopted. On the other hand, conventional tillage during fallow reduces soil organic matters levels at the soil surface and increases wind and water erosion.

APPROACH: This study was originally established in 1967 by Darryl Smika, modified by Ardell Halvorson in 1989, and modified again by Merle Vigil and Randy Anderson in 1996. In 1967 four weed control strategies during fallow were compared. These were no-till (residual and contact herbicides only), reduce-till (residual herbicides in August after wheat harvest followed by tillage the next summer after residual herbicides had failed), stubble-mulch (sweep-plow managed summer fallow), and a moldboard plow treatment.This core set of plots has been kept since 1967. We have added a four year rotation of wheat-proso millet (or corn depending on weed and moisture conditions)-sunflower-summer fallow. This rotation was established to evaluate long term changes in soil Carbon and soil organic matter as influenced by intensive management. Other studies of an academic nature have included: a Delta ^{13}C dating of soil organic matter pools, studies to evaluate infiltration and compaction as influenced by long term tillage, and studies to evaluate fungal verses bacterial activity as influenced by tillage.

RESULTS: In general the no-till plots have not produced better than the tilled plots. The moldboard plow plots are less weedy then either the sweep tilled plots and/or the no-till or reduce till plots. The plots that have been exclusively in a wheat-fallow rotation are infested with jointed goat grass and cheat grass. Plots that have had a three year rotation of wheat-corn-fallow are relatively much cleaner with respect to weeds. Soil organic matter levels are being evaluated as a function of tillage and soil depth. The largest difference (as you might expect) is with lower surface organic matter levels in the moldboard plow treatment as compared with the no-till plots. Nearly 15 times more fungal activity is measured in the surface 15 cm of these soils then bacterial activity with no significant differences between tilled and no-till plots.

FUTURE PLANS: Grassy weed pressure is so intense that we will not grow winter wheat on the land for the next 4 years. Oats or peas will be substituted for winter wheat over the next few years until we get control of the cheat and jointed goat grass problems. Because of its long term history the experiment has become valuable for looking at long term changes in soil organic matter, total soil N and C and changes in soil tilth at the soil surface. The experiment has been identified as a unique part of a network of long term experimental sites across the United States and Canada. Long term changes in soil surface C and soil tilth are being evaluated across that site network. We would like to keep the experiment going for 8 years in order to complete 2 cycles of the four year rotation.

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MISSION STATEMENT

The mission of the Great Plains Systems Research Unit (GPSR), Northern Plains Area, Fort Collins, Colorado is to enhance the economic and environmental sustainability of agricultural systems by:

1. Quantifying and enhancing scientific knowledge at the whole-system level.

2. Developing integrated computer models of agricultural systems and supporting their application to field research projects and the analysis of major issues--production, resource conservation, climate change, and precision farming.

3. Providing farm-level computerized decision support technology packages to farmers, ranchers, agricultural consultants and action agencies for evaluating the sustainability of alternative integrated farming and precision farming options.

TECHNOLOGY TRANSFER

Farmers - With the release of the GPFARM beta version, six farmers participated as beta testers and attended training in either Fort Collins or Akron Colorado.

NRCS, Extension Service, and other ag-service providers - Twelve ag-service providers participated in beta-tester training for the GPFARM beta release. Two representatives of the Northern Colorado Water Conservancy District received training in the use of NLEAP.

Science and Research Community - Twelve ARS or Colorado State University scientists participated in the GPFARM beta version release and beta-tester training. Three foreign scientists received training in the use of NLEAP.

CRADA - The CRADA with Water Resources Publications, of Englewood, CO, made significant progress in 1997. Drafts of the final document were received, edited and return to publisher for publication.

CRADA - CRADA with J.R. Simplot, Inc. - NLEAP computer code containing modifications needed for fertilizer recommendations was delivered to Simplot. Cooperative efforts are continuing to merge the NLEAP fertilizer version with Simplot's user interface for fertilizer dealers.

CRADA - A new CRADA was initiated with Columbia Cascade Inc. for developing a management and information system.

CRADA - Participating in a CRADA initiated by ARS-Temple, TX, with the Giddings Equipment Co.,Fort Collins, Colorado, to test soil penetrometer and GPS technology.

Farmers - Two hundred fifty farmers received the results of the *Farm Computer Use in the Great Plains* survey administered by this unit. Presentation was made to Akron Research Station customer focus group on GPFARM.

Science and Research Community - Continued testing of RZWQM.

Science and Research Community - Unit scientists presented four invited paper and eighteen volunteered papers.

Unit scientists authored or co-authored seventeen refereed journal articles, four book chapters, and two extension fact sheets or reports.

SIMULATION OF NITRATE IN SUBSURFACE DRAINAGE FROM MANURED PLOTS USING RZWQM

L.R. Ahuja, Ajay Kumar[1] and R.S. Kanwar[1]

PROBLEM: Computer simulation models such as RZWQM provide a cost-effective and time saving alternative to lengthy and expensive field studies for evaluating various agricultural management option. However, the model performance has to be critically evaluated against observed data collected in the controlled experiments before the model can be accepted as a tool for evaluating management scenarios. This project focuses on the critical evaluation of the model performance.

APPROACH: The Root Zone Water Quality Model (RZWQM, V 3.25) was used to simulate the effect of swine manure applications on nitrate-nitrogen (NO_3-N) concentrations in the subsurface drain water under continuous corn for Iowa soils. Several parameters of RZWQM were calibrated to provide satisfactory subsurface drain flow, nitrate in drainage water and nitrate in soil profile for growing season of 1993. The calibrated parameters were then used to simulate subsurface drain flows, its NO_3-N concentrations, and residual NO_3-N content in the soil profile as affected by manure application for growing season of 1995. Simulated subsurface drain flows, NO_3-N concentrations, and total residual NO_3-N were compared with the measured values.

RESULTS: Predicted daily subsurface drain flows by the RZWQM were close to the observed flows. Annual total subsurface drain flows predicted by the model were also close to the observed values (difference over two years was -3.9%). The predicted NO_3-N concentrations in subsurface drainage water followed the observed trends well for both years, 1993 and 1995, for all three plots. The annual average NO_3-N concentrations predicted by the RZWQM were also in close agreement with the measured values for 1993 and 1995 (within a difference of -3.0%). Linear regression (zero interception) between the predicted values for the pooled data (average of three plots for two years) and the measured data gives a R^2 value of 0.88 with a slope of 0.96. The predicted soil NO_3-N contents in 0-1.2 m soil profile were also in close agreement with the measured values in the field. The overall results of this study indicate that RZWQM is capable of simulating various rate of manure applications in different weather and soil conditions. A paper was written from this study and has been accepted for publication in the transactions of the ASAE.

FUTURE PLANS: Future plans include: a) Further evaluation of the manure component; and b) simulate long-term impacts of chemical (multiple N- application, banding, manure application, etc.), management and crop rotation on water quality.

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SPATIAL AND TEMPORAL VARIABILITY OF SOIL PROPERTIES ACROSS LANDSCAPES: CROP YIELDS, PRECISION AGRICULTURE, AND SIMULATION MODELING.

L.R. Ahuja, M.J. Shaffer, M. Peterson[1], M. Sucik[1],
R. Grossman[1], D. Harms[1], J. Cipra, M. Nachabe[2] and M.K. Brodahl

PROBLEM: The spatial and temporal variability of soil properties and their effects on crop yield as influenced by management and climate across farm fields is not well understood, especially in light of recent developments and interest in precision agriculture and decision support systems such as GPFARM.

APPROACH: A cooperative project was initiated involving USDA-ARS, Fort Collins, CO; NRCS in Lakewood, Greeley, and Akron, CO; NRCS in Lincoln, NE; and CSU. The purpose was (1) to evaluate the level of NRCS soil survey needed for addressing precision farming problems in dryland agriculture of Eastern Colorado and for use in decision support models, (2) to determine the extent to which soil survey results can be used to estimate the distribution of soil properties over a landscape for modeling purposes, (3) to determine how to account for use-dependent changes in soil attributes, (4) to collect soils, crop yield, and weather data suitable for testing GPFARM, and (5) to begin determining the dominant soil, landscape, and other factors controlling spatial and temporal yield variability in dryland agriculture in eastern Colorado.

RESULTS: Soils on the majority of the G. Lindstrom farm were mapped and georectified in the spring of 1997 using an order 2 soil survey. Baseline and recurrent soil attribute data were collected in 1997 for use in landscape characterization, to look for use-dependent changes in soil properties, and for use in testing the GPFARM decision support system across the farm. Wheat yield monitor data were collected in July 1997 on three 160 acre fields. Yield results showed high spacial variability across each field with wheat yields ranging from about 10 to over 80 bu/ac. The northeast field contained considerable topographic relief and all three fields showed the highest yields in the depressional areas and lowest yields on the ridges. High correlations (>0.93) were found for the yield distributions versus surface soil color. A comparison of the wheat yield maps with the order 2 soil survey maps indicated that the best correlation was obtained for the northeast field (higher topographic relief) with a poorer correlation for the south field (less topography).

FUTURE PLANS: Determine the relative contributions of soils, management, pests, and climate to crop yield variability across fields and seasons in dryland agriculture.

[1]NRCS, Greeley, CO; Akron, CO; Lincoln, NE
[2]Colorado State University, Fort Collins, CO

PRECISION FARMING: MEASUREMENT AND VARIABILITY OF NEAR-STEADY STATE INFILTRATION RATE AND FIELD CAPACITY ON A FINE AND COARSE FIELD SCALE

L.R. Ahuja and G.H. Dunn

PROBLEM: Field scale variation in water infiltration rate is one important parameter in the study of precision farming techniques. Variations in infiltration rate affect run-off, plant available water, leaching, and irrigation efficiency.

APPROACH: Single-ring infiltrometers were used to measure infiltration rate at the field scale. Two sampling strategies, fine grid and coarse grid were used. The fine grid had nodes at 10 m by 10 m intervals and the coarse grid nodes were at 100 m by 100 m intervals. Infiltration was measured after infiltrometer rings were filled and drained over a period of one or more hours until a near-steady state infiltration was achieved. After the near-steady state infiltration rate was measured the site where the measurement was made was covered with plastic to prevent evaporation. Forty eight hours after the infiltration was measured soil samples were collected in depth intervals of zero to thirty centimeters (0 - 30 cm) and thirty to ninety centimeters (30 - 90 cm) for analysis of soil moisture content, bulk density, and soil texture.

RESULTS: Analysis of the infiltration data from the fine grid indicated a wide range in variation in infiltration. The variation was related to landscape position and may be related to soil depth. Not enough coarse grid samples have been collected to provide similar analysis. Bulk density, texture and soil moisture content indicated the soil was high in sand content with low water holding capacity.

FUTURE PLANS: Only a few of the coarse grid nodes were sampled in 1997, the remainder will be sampled in 1998. As a result of the soil sampling done as part of the infiltration study, a clay layer was discovered at varying depths in the soil profile. In addition, to completing the infiltration study the depth and thickness of the clay layer will also be measured.

EFFECT OF WHEEL TRACK VERSUS NON-WHEEL TRACK ON SOIL PORE SIZE DISTRIBUTION AND MOISTURE RELEASE

L.R. Ahuja, J.G. Benjamin[1] and G.H. Dunn

PROBLEM: On some no-till farms, tractors and harvest machinery follow the same track year after year creating permanent and visible wheel track areas. The soils in these wheel tracks are compacted and have different soil physical properties than the non-wheel track areas. This compaction may have an affect on water infiltration and run-off and pore-size distribution.

APPROACH: Soil cores were taken from wheel track and non-wheel track areas and on three landscape positions on two no-till plots in eastern Colorado. The cores, taken from the one to four inch depth, will be analyzed for saturated hydraulic conductivity and moisture desorption.

RESULTS: Work has begun to analyze the cores for saturated hydraulic conductivity and moisture desorption.

FUTURE PLANS: Additional cores will be taken from the same plots and landscape positions, these cores will be from the top one inch of the profile and will be analyzed for moisture desorption particularly in the wet range.

[1]USDA-ARS, NPA, Central Great Plains Research Station, Akron, CO

FIELD DECOMPOSITION RATES AND SOIL COVER OF SURFACE CROP RESIDUES

R.M. Aiken[1] M. Vigil[1], G. Uhler[1] and M.J. Shaffer

PROBLEM: Surface crop residues reduce soil erosion and can improve soil water storage, conditioning the biological environment of crop seedlings and associated pests. Decomposition of surface residues alter these benefits and biological risks, and may compromise conservation compliance of dryland cropping systems. Knowledge of environmental factors altering decomposition rates can guide surface residue management.

APPROACH: Seasonal decomposition rates of surface crop residues (whet, millet and corn) were measured under field conditions using litter bags, screen shelters and grab samples, collected at 1000 degree day intervals. Changes in biochemical composition of residues were sampled at initial, mid and final stages of field exposure. Accumulation of surface crop residues in various wheat, corn and millet crop sequences of the Alternative Crop Rotation study was determined pre-plant and post-harvest over four crop seasons. We quantify daily temperature effects on decomposition rates using a first order rate model, scaled to thermal time (cumulative degree days).

RESULTS: The number of standing stems decreased linearly over the fallow period (<14 months). Loss of soil cover resulted from residue decomposition during warm and wet spring conditions, and was likely accelerated by mechanical action of wind during cold winter conditions. We observed similar decomposition rates among the crop residues. Fiber analysis appears to provide a means of quantifying nutrient pools within crop residues. The half-life of standing plus surface residues appears to be 5800°C day, about 1.5 years of calendar time, while a shorter half-life for surface residues under wet soil conditions indicates more rapid decomposition.

FUTURE PLANS: A manuscript reporting results is in preparation.

[1]USDA-ARS, NPA, Central Great Plains Research Station, Akron, CO

SEASONAL RESIDUE IMPACTS ON RADIATIVE DRYLAND CONVECTIVE EXCHANGE PROCESSES

R.M. Aiken[1], D. Nielsen[1] and L.R. Ahuja

PROBLEM: The distribution of standing and flat surface crop residues condition the habitat of crop seedlings and associated pests. Cooler and wetter soils, associated with no-till crop management, alter decomposition rates of surface residues as well as soil quality factors impacting water management. Knowledge of residue effects on surface microclimate and subsequent processes can guide soil and water management.

APPROACH: We installed radiation, temperature, wind and soil water sensors in 10 m x 30 m plots of standing wheat, millet, corn and sunflower residues following harvest. Hourly data acquisition was screened for sensor reliability prior to archiving for subsequent analysis. Sheltering and insulating effects of crop residues are quantified as solar reflectance and wind velocity at 0.2 m relative to reference wind speeds at 2.0 m. Cover of flat residues and persistence of standing stems were sampled periodically. An energy balance simulation module of the Root Zone Water Quality Model quantified residue effects on evaporative demand.

RESULTS: Soil-residue systems differ in absorbed solar radiation, in relative windspeed at 0.2 m, and in near surface temperature dynamics. Simulation results indicate the shading and insulating effects of crop residues can reduce potential evaporation by 30 to 70%, relative to bare soil, under wet soil conditions. Effects of standing stems on light transmission and wind speed profiles can be quantified using light extinction and wind profile theory. Relationships derived for plant canopies can be adapted to standing stems, and are in qualitative agreement with observations.

FUTURE PLANS: A manuscript reporting results is near completion.

[1]USDA-ARS, NPA, Central Great Plains Research Station, Akron, CO

SURFACE CRUST FORMATION AND EFFECTS ON WATER, HEAT AND AIR TRANSPORT

R.M. Aiken[1], J.G. Benjamin[1], R. Bowman[1], L.R. Ahuja and G. Dunn

PROBLEM: Surface soil crusts, formed by raindrop impact on exposed soil, restrict infiltration, soil aeration, and seedling emergence. Crusts can limit soil intake of water from intense rains of convective thunderstorms. Surface crusts limiting infiltration can reduce the quantity of water available for dryland cropping systems in the region; runoff associated with surface crusts can lead to soil loss as well. Previous studies indicate crust formation depends on rainfall intensity, soil characteristics (texture, cation composition, soil organic matter) and soil wetting conditions prior to rainstorm events.

APPROACH: We will use simulation models and rainfall simulators under controlled and field conditions to test the hypothesis that the settling depth of disaggregated and dispersed soil particles depends on rainfall intensity, relative to soil internal drainage capacity. We will use standard methods to measure surface soil strength and transport capacity of water, heat and air before and after crust formation. We will investigate use of micromorphologic methods to quantify crust properties. Soil properties known to affect crust formation will be determined for each experimental condition.

RESULTS: Nearly half the annual precipitation recorded at the Central Great Plains Research Station occurred in events exceeding 0.75", though these events comprised only 13% of annual events. Storms of this magnitude appear capable of inducing crust formation, while also exceeding the sorptive capacity of an initially dry 3" soil layer. Rainfall intensities ranged from 0.04 in./hr. to 3.19 in./hr. with accumulations ranging from 0.08" to 0.91" during selected storm segments.

FUTURE PLANS: We are completing simulation of relative rainfall intensities on pore water velocities; the results will guide rainfall simulator studies to be conducted in the spring of 1998. Initial studies will be conducted under laboratory conditions using sieved soil packed into pans. Field studies will investigate either effects of cropping intensity or topsoil removal on crust formation. We are exploring collaborative work with Soil Microbial Systems Laboratory to relate aggregate strength to concentrations of the glycoprotein "glomalin", thought to derive from arbuscular mycorrhizal fungi.

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SIMULATING YEAR-ROUND ENERGY AND WATER FLUX UNDER CROP RESIDUES

R.M. Aiken[1], G.N. Flerchinger[2], L.R. Ahuja, H.J. Farahani and K.W. Rojas

PROBLEM: Residue architecture (standing height, percentage soil cover, reflectance, etc.) modifies soil warming and water conservation by shading and 'insulating' surface soil layers. Decay of residue, dependant upon temperature and water conditions, results in seasonal changes in residue architecture, with impacts on soil temperature and water status. Accurate simulation of energy and water exchange processes provide analytic tools guiding residue management.

APPROACH: Crop residue impacts on energy and water exchange are quantified by PENFLUX, a soil-residue energy balance module providing boundary conditions for soil heat and potential evaporation modules of the Root Zone Water Quality Model (RZWQM). Year-round simulation of residue impacts by RZWQM is provided by incorporating energy exchange modules of SHAW, a process-level simulation model including freeze-thaw thermal dynamics of soil. Predictive accuracy of energy balance simulation is determined by comparing simulation results with micrometeorological observations acquired under dryland wheat, corn, sunflower and millet residues at the Alternative Crop Rotation experimental site.

RESULTS: Non-calibrated simulation of surface energy balance demonstrated high precision with persistent bias for net radiation (R^2>0.99) and surface temperature^2 (R >0.86). Simulated evaporation, confirmed by soil water measurements, was greatest for systems with lowest residue cover--sunflower_NT and wheat_SM.

FUTURE PLANS: The PENFLUX module requires a companion residue water balance, under development, for accurate simulation of thermal conditions following precipitation/dew accumulation events. We will modify radiative and convective transport processes based on standing stem effects reported in this document. Further evaluation of RZ_SHAW and PENFLUX modules will utilize extensive micro-meteorological data acquired at Pullman, WA; Fort Collins, CO; and Akron, CO representing a range of residue architectures in semi-arid climates. Manuscripts reporting the predictive accuracy of these modules under winter and non-freezing conditions are in preparation.

[1]USDA-ARS, NPA, Central Great Plains Research Station, Akron, CO
[2]USDA-ARS, PWA, Watershed Management Research, Boise, ID

DEVELOPMENT OF A FARM SPATIAL DATA MANAGEMENT SYSTEM MODULE FOR GPFARM

J.C. Ascough II, H.D. Rector and B.G. Faber[1]

PROBLEM: A farm spatial data management system (FSDMS) is necessary for transforming data from a georectified map or nongeorectified image format to a data format acceptable to GPFARM. The selection of areas having homogeneity for simulation by GPFARM requires geographic information system (GIS) functionality for evaluating a variety of GIS data layers representing different spatial attributes, not necessarily spatially coincidental. An additional capability of the FSDMS is the capability of providing map and table output for storage, and management of attributal data relating to the maps or images.

APPROACH: The project runs in the ESRI, Inc. ARCVIEW 3.0a environment under Windows 95 and Windows NT. FSDMS is being developed with AVENUE, a scripting language specific to ARCVIEW. ARCVIEW is a GIS designed specifically for viewing, modifying, and storing image and map data. Enhancements to FSDMS are made to tailor the sketching, mapping and attribute storage information to the GPFARM data input and output requirements. The FSDMS anticipates three different user groups characterized by different levels of information storage, mapping needs, and levels of experience with GIS technologies. Level I capability presumes that users will import and store non-georectified images and related attribute data. This spatial data may be converted to map information (georectified to a geographic coordinate system) in the future. Level II provides the user with capabilities to import maps and map attribute data. This increasingly complex usage level also provides GPFARM interface capability primarily focused toward the cooperator or agricultural consultant who will use the geospatial capabilities of the FSDMS in conjunction with GPFARM simulation procedures. Level III provides the researcher with full GIS tools for conducting research-level geospatial analysis with GPFARM.

RESULTS: The development of the FSDMS is coincidental with the development of GPFARM. The FSDMS Level I and parts of Level II will be linked to GPFARM during the summer of 1998. Customized on-line help screens are being developed to assist the users with the menu-level items and features of the FSDMS.

FUTURE PLANS: Level II will be completed in late 1998 and Level III will be completed in 1999. Level III is planned to include neural network/artificial intelligence-based prescriptive farming components to complement and use the simulation outputs of GPFARM, and other ARS simulation models such as NLEAP.

[1]CIESIN, Consortium for International Earth Science Information Network

THE AGRICULTURAL MODULAR MODELING SYSTEM: A PROBLEM SOLVING APPROACH FOR AGRICULTURAL SYSTEMS

L.R. Ahuja, J.D. Hanson, K.W. Rojas and Chad Bierbaum

PROBLEM: Computer models continue to gain importance as planning tools in a wide variety of research arenas. In the next decade, the coupling of computer modeling with management decision support will play a vital role in agricultural research and application. To address this continuing demand, the Agricultural Modular Modeling System (AMMS) will provide a reusable software framework for developing, running, and analyzing models to solve specific agricultural problems. The system will be designed so non-modelers having a specific problem, can use the system for developing a stand-alone package designed specifically to address the problem. Implicitly, the process library must contain a wide range of processes and methods for simulating those processes. The system must also be able to account for problems from various spatial and temporal domains.

APPROACH: Increased user demand coupled with modern computer hardware capabilities has necessitated advances in research software sophistication. Historically, the trend in modeling approaches was that individual models incorporate all aspects of the required sophistication. However, in modern software design, proven reusability is achieved by moving away from the single purpose model and towards universally applicable modeling frameworks, which offer a variety of built-in capabilities. In the case of AMMS, the framework will provide tools for: visualization and graphical representation of data; sophisticated and extensible user interface capabilities; interoperability with other tools; and variability and number of process modeling approaches which are documented and maintained in a modeling library.

RESULTS: At *The Inter-Agency Workshop on the Development of a Modular Modeling Framework*, a prototypical system was demonstrated which incorporated some of the features described above. The development of this initial system was a shared responsibility between the USGS (Leavesley et al., Denver, CO) and the AMMS development team (Ahuja et al., Ft. Collins, CO). This system demonstrated the viability of these approaches in modeling and serves as the basis for ongoing development in the AMMS framework. This demonstration highlighted the importance of the 'open' design architecture employed in AMMS. This design achieves a clear separation between the modeling framework and the modeling library. With this type of layout, it is possible to adopt new modeling algorithms and enhanced system tools without impacting existing implementation.

FUTURE PLANS: Continuing work for AMMS is tied to enhancing the following system features: an improved GUI to achieve visual construction and application of models; testing and continued development of the Modeling Engine which is responsible for linking and execution of the model; and implementation of additional modeling related code in the Modeling Library.

MODELING FURROW IRRIGATION POSITION AND FREQUENCY EFFECTS ON WATER STRESS AND WATER LEACHING LOSSES IN CORN (*ZEA MAYS* L.)

J.G. Benjamin[1], H. Ruan[2] and L.R. Ahuja

PROBLEM: Furrow irrigation is an inefficient method for application of irrigation water, but is used in many areas of the United States because of low equipment costs. Compared with sprinkler irrigation, furrow irrigation typically uses more water for each irrigation event and has longer intervals between irrigations. This leads to the danger of deep irrigation water losses because, to apply sufficient water at the end of the field furthest from the water source, over irrigation occurs in the portion of the field near the water source. The excess water will leach from the root zone of the crop and into the groundwater. To minimize deep leaching losses of irrigation water, the producer can apply less water for each irrigation, but then there is the concern of possible plant water stress in the portion of the field farthest from the water source.

APPROACH: We used the ROOTGRO model to evaluate the effects of irrigation scheduling and timing on deep leaching water losses from the soil and potential plant water stress. We calibrated the model with data from a field experiment conducted in 1994 and 1995. The experiment consisted of every-furrow and alternate-furrow irrigation water placement with a weekly irrigation schedule equivalent to 100% ET. We then conducted simulations to examine: a) an irrigation schedule sufficient to supply water at 100% ET but on a bi-weekly basis instead of a weekly basis; b) irrigation amounts of 70% ET on a weekly basis and; c) irrigation amounts of 200% ET on a weekly basis. We evaluated deep water losses and plant water stress from each set of simulations.

RESULTS: The differences between model predictions of water contents and the measured values were numerically similar to the variation among replications from the field experiment indicating good predictions from the model. Changing from a weekly to a bi-weekly irrigation schedule resulted in predictions of plant water stress late in the growing season, but not early in the growing season. Changing the irrigation amounts from 100% ET to 200% ET resulted in all of the additional water being lost to deep leaching. Changing the irrigation amounts from 100% ET to 70% ET resulted in low deep leaching losses of water and, yet, did not result in predicted plant water stress because of sufficient soil water storage. We concluded that it is more efficient to under-irrigate the portions of a field far from the water source in order to decrease the deep leaching near the water source.

FUTURE PLANS: We plan to calibrate the model for nitrate, bromide and atrazine in order to examine the effects of irrigation scheduling on solute movement in a furrow field.

[1]USDA-ARS, NPA, Central Great Plains Research Station, Akron, CO
[2]Colorado State University, Fort Collins, CO

THE EFFECTS OF TILLAGE ON WEED SEED BANK COMPOSITION AND DISTRIBUTION

S.R. Canner[1], L.J. Wiles[2], G.S. McMaster and R.H. Erskine

PROBLEM: Producers across the Great Plains are reducing tillage to protect and improve the soil resource, yet many are reluctant to further reduce tillage because of concerns about weed management. While the immediate effects of burial on weed seeds are reasonably well known, less is known about long-term impacts of a tillage system on weed community composition or on weed seed distribution in the soil profile. This information is essential to the development of strategies for weed management in reduced-tillage systems which are cost effective and environmentally benign, and for modifying the Weed Component of the GPFARM decision support system.

APPROACH: A long-term comparison of tilled vs. no-tilled wheat-fallow systems was initiated in 1991. (See report on DRYLAND WINTER WHEAT PRODUCTION SYSTEM RESPONSES TO SOIL MANAGEMENT PRACTICES). In late summer 1997, we took ten eight-inch deep soil cores in each of the normal residue plots. Cores were divided into one-inch depth increments. Soil cores were taken again immediately after tillage in the tilled plots, to contrast the effects of long-term tillage management with the short-term effects of a single tillage event. Weed seeds were separated from soil by washing through a fine screen and weed seeds were identified and counted for each sample.

RESULTS: Data collection is nearly complete.

FUTURE PLAN: Analyze and summarize the data, then use to evaluate models for the effects of tillage on weed population dynamics, particularly for the Weed Component of GPFARM.

[1]Colorado State University, Fort Collins, CO
[2]USDA-ARS, NPA, Water Management Research Unit, Fort Collins, CO

DEVELOPMENT AND TESTING OF A CROP GROWTH MODEL FOR GREAT PLAINS AGRICULTURE

L.A. Deer-Ascough[1], G.S. McMaster, J.C. Ascough II, G.A. Peterson[1] and L.R. Ahuja

PROBLEM: Across the Great Plains, using and supplementing water and nitrogen resources to enhance agricultural production without damaging the environment is a major challenge. To meet this challenge, the GPFARM DSS was developed to analyze and develop strategic management plans. GPFARM includes a simulation model consisting of modules for simulating various biological, physical, and chemical processes of crop-animal production systems. Simulation models such as GPFARM require a plant growth component. However, because of model program structure, treatment of crop stresses (e.g., water, temperature, and nutrient), and types of crops parameterized, current plant growth models are unsuitable for direct insertion into GPFARM without further development, modification and testing.

APPROACH: GPFARM uses the WEPP crop growth model which is based on the EPIC crop model. A single generic model is used for simulating several crops by changing model parameters. Biomass production and crop yield predicted by the plant growth component is available as a model output.

RESULTS: The GPFARM crop growth model was validated using test plot data from three sites in Eastern Colorado. Yield data (1987-1996) collected from rotations of: 1) winter wheat, dryland corn, and fallow (WCF); and 2) winter wheat and fallow (WF) on the summit portion of each test plot were used for validation. The absolute relative error for observed versus GPFARM predicted yield values and the R^2 regression statistic were calculated. In general, the R^2 results were low (0.19 to 0.51), however, these values reflect GPFARM simulation results without the benefit of plant growth parameter calibration. The average absolute relative error across the three sites and two cropping rotations was 35%, which is reasonable for an initial validation attempt. This relative error magnitude is typical for generic plant growth models of this type.

FUTURE PLANS: Future work for the GPFARM generic crop model will include the improvement of crop parameters for Colorado and Great Plains agriculture systems. Model input parameters will be expanded to reflect other crops grown in the Great Plains region. Enhanced stress algorithms, particularly for water stress, are needed for GPFARM. Seedling emergence, root, and phenology submodels will also be added which should result in improvement of the current model. Further validation and testing will be performed on additional data sets.

[1]Colorado State University, Fort Collins, CO

ROOT ZONE WATER QUALITY MODEL

J.D. Hanson, K.W. Rojas and L.R. Ahuja

PROBLEM: Recent research has shown that agricultural management of land use and tillage systems can have a very significant impact on hydrologic and chemical response. Detailed process modeling has been used to analyze the effects of different management schemes on crop production and environmental sustainability. The Root Zone Water Quality Model (RZWQM) was developed as a state-of-the-art simulation model for evaluating the impact of cropping systems on water quality in the rooting zone.

APPROACH: RZWQM was developed using standard programming techniques. Subsequently, the model was used in conjunction with the Management Systems Evaluation Area (MSEA) project. Thorough evaluation of the model was accomplished at each MSEA site and substantial improvements were made to the model. Following the completion of the RZWQM code, a Windows© 95 graphical user interface was developed for ease of use. Finally, the RZWQM program, documentation, and data sets were combined into a book.

RESULTS: RZWQM has been used on several data sets with good results. The technique for calibrating the model has also been developed. The user interface was designed to allow scenario runs of the model and view graphical and textual output. It has been coded and thoroughly tested. A CRADA was developed with the Water Resources Institute to publish RZWQM. The book chapters have been compiled, edit, and resubmitted to WRI. Distribution of the book with the RZWQM CD is forthcoming.

FUTURE PLANS: The completion of the RZWQM book will mark the end of development on this model. Component of RZWQM will be incorporated into a new modular modeling system, currently under development. Some maintenance will be required, but this will be minimal.

DECOMPOSITION OF SURFACE RESIDUES IN LONG-TERM STUDIES IN DRYLAND AGROECOSYSTEMS

L. Ma, G.A. Peterson[1], L.R. Ahuja, L. Sherrod, M.J. Shaffer and K.W. Rojas

PROBLEM: Crop residue has multiple roles in maintaining agroecosystem stability. Numerous studies have been conducted to determine its effects on nutrient availability, soil evaporation, energy balance, soil erosion, and physical and chemical soil properties. It is commonly accepted that residues are needed for soil sustainability, but excess amount of surface residues can cause problems with tillage, seedling, pesticide efficiency, and soil fertility. Therefore, prediction of surface residues on soil surface is important for agricultural management, especially under on-till conditions.

APPROACH: The ARS Root Zone Water Quality Model (RZWQM) has incorporated a procedure to predict surface residue decomposition based on degree-days (Douglas and Rickman 1992, SSSAJ 56:272-278). However, the model has not been tested for multiple year crop production. In this project, we tested the Douglas and Rickman model for a 13 year residue decomposition study in eastern Colorado along with three other models in the literature. The three models are Gregory model (Gregory et al. 1985, Trans. ASAE 28:98-101), decomposition-days model (Steiner et al. 1994, Agron. J. 86:76-81), and first-order decay with time (Collins et al. 1990, SSSAJ 54:780-785).

RESULTS: The models were tested using data collected in Sterling, Stratton, and Walsh counties in eastern Colorado with yearly mean air temperature of 9.7, 10.4, and 12.0 °C. Based on simulation results from all the slope positions and crop rotations at each experimental site, the Douglas and Rickman model was statistically better in fitting experimental data than the Gregory model. However, both models performed equally well in terms of predicting residue decomposition. Fitted rate constants were not significantly different among all three experimental sites when the Douglas and Rickman model and the Gregory model were used. Rate constants were significantly different when decomposition-days model and a first-order decay with time model were used. Estimated average percentage of yearly residue decomposition was 43% based on the Douglas and Rickman model for the Colorado dryland no-till agroecosystem.

FUTURE PLANS: We will further test these models in the RZWQM framework.

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SENSITIVITY ANALYSIS OF THE ROOT ZONE WATER QUALITY MODEL FOR AGRICULTURAL MANAGEMENT

L. Ma, L.R. Ahuja, M.J. Shaffer, J.D. Hanson and K.W. Rojas

PROBLEM: The Root Zone Water Quality Model (RZWQM) has completed its initial testing stage and is ready to be released to the public for further evaluation. However, testing on its response to agricultural management is lacking, such as crop and nitrogen responses to irrigation, tillage, fertilizer application, and manure management.

APPROACH: One data set from Colorado and data sets from the Management Systems Evaluation Area (MSEA) project in Iowa, Missouri, Georgia, Minnesota, Nebraska, and Ohio will be used to test the sensitivity of RZWQM to appropriate management practices. The use of new Window95 interface (RZWQM98) will facilitate the sensitivity analysis.

RESULTS: Initial analysis of RZWQM for manure management for the Colorado data set showed that the manure application rate of 44.8 Mg/ha/yr and irrigation rate of 20 cm/event caused extensive nitrogen losses to the environment through leaching, denitrification, and volatilization. Reducing those rates to 50% would not affect farmer's yield but significantly decrease environmental fates of nitrogen. Further evaluation of RZWQM for other management for all the data sets is underway and will be reported in 1998 annual reports.

FUTURE PLANS: We will complete the sensitivity analysis for all the management practices and all the data sets in 1998.

TESTING RZWQM FOR MANURE MANAGEMENT UNDER FIELD CONDITIONS

L. Ma, M.J. Shaffer and L.R. Ahuja

PROBLEM: Animal waste disposal has received great attention in agriculture for the last decade. Many studies have shown that extensive use of animal wastes on agricultural land may cause potential contamination of groundwater and surface water bodies. Therefore, it is necessary to develop improved management practices for manure. The RZWQM was developed to simulate management effects on leaching of nitrates under a range of management conditions, but requires testing for manure.

APPROACH: Two sets of field experiments with beef or chicken manure were selected to test the RZWQM. One is from Colorado, where beef manure was applied continuously to a corn field for more than 10 years, and the other is from Arkansas, where chicken manure was applied to a tall fescue field which had not received any fertilizers for many years prior to experiment. In both fields, crop nitrogen uptake, nitrate in the soil profile, and soil water content were measured periodically. The results were used to calibrate/validate the RZWQM for soil water content, matrix potential, temperature, total nitrate in the soil profile, and crop yields. The calibrated model was then used to simulate long term effects of manure management under the specific field conditions.

RESULTS: For the Colorado experiment, the RZWQM was calibrated for crop yield and nitrogen uptake in 1994 and 1995, and then used to predict crop yield and nitrogen uptake in 1996, soil water storage in 1994 and 1995, and soil nitrate concentration in all the three years for both the manured and non-manured plots. The model correctly predicted crop yield and nitrogen uptake within one standard error. Predicted soil water storage was highly correlated to experimental measurements (r^2=0.82). The model also predicted the response of soil nitrate to manure applications. These results will be published by SSSAJ in 1998. For the Arkansas experiment, the RZWQM was calibrated for soil water content and soil matrix potential. Tall fescue growth was simulated with a complementary threshold function fitted to experimental measurements. Model parameters for manure management was from calibrated values of the Colorado experiment. The model correctly predicted the response of soil nitrate to manure application and soil temperature at several depths. However, the prediction of nitrate in suction lysimeters was poor, which probably was due to poor characterization of the soil profile. Simulation results will be published in Soil Science in 1998.

FUTURE PLANS: We will further test the RZWQM for other manure experiments when data are available.

DRYLAND WINTER WHEAT PRODUCTION SYSTEM RESPONSES TO SOIL MANAGEMENT PRACTICES

G.S. McMaster, Dan Palic, Gale Dunn, Rob Aiken[1] and L.R. Ahuja

PROBLEM: In dryland wheat production systems, no- or low-tillage practices that preserve residue cover are being promoted. Pre-plant tillage practices can alter wheat germination and subsequent development and growth. Because wheat can reach grain yield in many ways, understanding how and why wheat responds to alternative soil management practices is needed.

APPROACH: First we need to understand how soil management practices alter fundamental factors such as soil temperature, water, and nutrients. Changes in these factors can then be measured for their effect on wheat physiology and development, and therefore help us better understand why the observed yield differences occur. Starting in 1991, pre-plant tillage practices (pre-plant tillage, PT; no-till, NT) and residue cover levels (no residue, 0R; normal residue, 1R; twice-normal residue, 2R) have been tested. Soil and air temperatures, soil water, soil nutrient levels, and heat and gas fluxes over time have been followed, and subsequent responses in wheat development and growth observed.

RESULTS: Pre-plant tillage loses seedbed water due to evaporation, whereas NT normally retains sufficient water for imbibition below a thin, dry surface layer. Farmers usually plant winter wheat "to water," but if tillage results in soil drying to a depth of 15 cm or greater, then germination will rely on September and October rains, especially if the dry layer exceeds the coleoptile length which restricts planting depth. Sufficient Sept/Oct rains for imbibition occur in many years, but in 3 of the last 7 years this did not happen. For six years of emergence data, in 3 years NT treatments had earlier emergence than PT (the 3 years without Sept/Oct rains). In four years, NT had more seedlings emerge (for 2 of these years, emergence was not earlier than PT). Greater canopy development due to earlier/more seedlings in NT combined with residue cover resulted in more available soil water in the profile at the time of spring greenup in NT plots. Presumably this is because of greater snow capture and reduced evaporation. Spring is critical because this is when most yield components, especially the number of spikes and kernels are being determined, therefore setting the yield potential. When and how the stand is established appears to determine final yield through impacts on the amount and timing of soil water. Final yield is highly correlated with time of emergence and number of seedlings emerged.

FUTURE PLANS: This year (1997-98) will likely be the last year of this long-term experiment. The probability of sufficient rainstorm events in Sept and Oct for imbibition needs to be calculated.

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COMPARING THREE DEVELOPMENTALLY-DRIVEN CROP GROWTH MODELS

G. McMaster, W. Wilhelm[1], R. Rickman[2] and M. Guzy[3]

PROBLEM: Many crop simulation models have been constructed, but generally evaluation of them has been poor and almost never have several models been evaluated on a common data set that spans diverse climates and soils.

APPROACH: Most crop simulation models are driven by photosynthesis. Three alternative approaches have been created that are developmentally-driven models. These models are SHOOTGRO, MODWht, and Modwht++. To evaluate how well these three models simulated wheat growth, development, and yield, a diverse data set was collated covering different cultivars and management practices. Sites were located in the Great Plains (8 sites), Pacific Northwest (2 sites), California (1 site), Georgia (1 site), Canada (1 site), and North Dakota (1 site), with from one to six years of data at each site.

RESULTS: Each model had its strengths and weaknesses, but generally predicted phenology very well. SHOOTGRO predicted phenology over a wide range of cultivars and sites slightly better than the other models. MODWht predicted yield slightly better than the other models. Since SHOOTGRO simulates greater detail than the other models by simulating each leaf blade and sheath, internode, and kernel dimensions and weight on each tiller of up to six age classes of plants, it could better simulate growth of specific tissues than the other models, but did not simulate the aggregated totals of leaves, stem, and seeds as well as the other models. Since SHOOTGRO has been compared under South African conditions to two other models that are photosynthesis-driven (CERES-wheat and PUTU) and shown to predict development better and be similar in yield prediction (slightly less accurate), we feel that this shows that development-driven simulation models not only provide an equally valid approach to crop simulation modeling.

FUTURE PLANS: If time permits, the work will be published in a journal. Also, as work is underway on building a new crop simulation research model, concepts will be taken from the five models listed and applied towards developing the new model.

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DEVELOPING USABLE AND UNIFORM GROWTH STAGE SCALES FOR SCIENTISTS AND INDUSTRY

G. McMaster and W. Wilhelm[1]

PROBLEM: For each crop, usually many growth stage scales have been developed. Selection of a growth stage for use depends on many factors including history of the region/group, needs of the user, and knowledge of the user. Researchers often select different growth stage scales than farmers, who select different scales than industry (particularly crop insurance) users. Clearly, there is a need for a unified growth stage scale for all crops that is sufficiently detailed to be useful to researchers but understandable by less-trained individuals.

APPROACH: In 1996, the Crop Science Society of America formed an Ad Hoc committee to address the issue of how to simplify the seemingly ubiquitous presence of growth stage scales. We felt that part of the solution to the problem was to expand a computer program we had developed (SCALES) for converting between three growth stage scales (Feekes, Zadoks, and Haun) of wheat to (1) include a new scale developed in Europe (BBCH), and (2) to convert among two main scales for corn and the BBCH scale. The reason for inclusion of the BBCH scale was that this scale was developed to stage most species. We called the expanded computer program SCALES 2.

RESULTS: The SCALES 2 computer program was completed so that conversion among major growth stage scales for small-grain cereals and corn is possible by a user inputting simple, easily obtained information. The computer program is available to interested users without cost. The manuscript will be published in the Agronomy Journal in 1998.

FUTURE: No anticipated future work unless industry asks for further extension of this product.

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MAPPING MANAGEMENT UNITS FOR PRECISION AGRICULTURE

M.H. Nachabe[1], L.R. Ahuja, M.J. Shaffer, J.C. Ascough II and M.K. Brodahl

PROBLEM: Dryland crop yield varies dramatically in space, sometimes changing by an order of magnitude within meters. The objective of precision agriculture is to optimize management practices according to site-specific conditions, thereby increasing crop yield and income while reducing over-application of inputs. In this research, we were interested in characterizing the spatial variability of winter wheat to determine the potential of adopting precision agriculture in eastern Colorado.

APPROACH: A yield monitor linked to GPS was used in harvesting winter wheat in three fields at Sterling, CO. The data was transferred into a Geographic Information System where maps of yield and topography were developed and geo-referenced. The GIS framework allowed the analysis of spatial variability. We considered three aspects of this problem. First, we evaluated the variance of yield at the measurement or support scale (9x9 meters) to assess whether the variability is significant enough to justify the need for precision agriculture. Second, we analyzed how this variance will change as one alters the spatial resolution of the support scale. Yield variability is said to follow a fractal behavior if the moments (e.g., variance) and the scale of resolution of variability obey a log-log linear relationship. A fractal behavior will be very useful because it provides a mean of linking variability across scales. Third, we were interested in comparing the statistical spatial properties of the fields to assess the similarity and universality of theses properties.

RESULTS: At the measurement scale (approximately 9x9 m), we found that yields vary by over an order of magnitude within a field with an average coefficient of variation of 0.5. The spatial variability followed closely a fractal behavior: the log of the variance decreased linearly with the log of scale of description, indicating that increasing the resolution will always reveal more details about the variability. This fractal behavior remained valid for spatial ranges from ten to over 500 meters, scales that are relevant to precision agriculture. Interestingly, the statistical fractal properties of the three fields studied were very similar, suggesting universality.

FUTURE STUDIES: In this early work, we showed how a fractal description of spatial variability can help mapping management units within a field. In the future, we are interested in linking this variability to physical processes and to sources of information easily accessible to producers. Preliminary results indicate certain topographical indices are quite successful in predicting the potential yield variation in the field.

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PLOT-FARM-ECOSYSTEM SCALE ANALYSIS AND PRECISION FARMING

J.A. Ramirez[1], J.D. Salas[1] and L.R. Ahuja

PROBLEM: Development of scientifically sound precision farming technology requires: (1) better understanding and quantification of the spatial variabilities of landscape, soils, and management, and temporal variabilities of weather and climate; and (2) relating the above variabilities and their interactions to the spatial and yearly variabilities of crop growth and yield. This same knowledge is also needed for relating plot scale experimental results to field and ecosystem scales for crop yield as well as environmental quality factors.

APPROACH: The main objective of this work is to obtain a complete characterization of the spatio-temporal variability of the geophysical fields involved in the transformation of rainfall into infiltration, runoff, and soil moisture and the interaction of the transformed fields with the processes of plant biomass production and crop yield. This characterization will be obtained as a function of scale.

RESULTS: A theoretical development to obtain a physically-based link between the characteristics of the spatial variability of observed dependent geophysical fields (i.e. soil moisture distribution, infiltration and runoff, and yield) and those of observed independent fields (i.e. precipitation/irrigation, topography, soil hydraulic properties) is in progress. This development will depend on an extensive data analysis, which will be based both on traditional geostatistical approaches as well as on new approaches based on scale invariance concepts. A thorough literature search was undertaken on topics related to a) scaling issues in hydrology and soil sciences; b) geostatistics and the description of observed spatial variability of soil and vegetation properties; c) rainfall-runoff modeling with models based on scaling concepts; and d) plant and ecosystem science and soil physics. Scaling and geostatistics analysis are underway for the yield data collected from Pivot 6 and Pivot 39 on Rothe's farm in Wiggins. These analyses will be extended to the other data fields mentioned above. The main objective of these analyses is to define the characteristics of the spatial variability of these fields as a function of scale and as a function of time.

FUTURE STUDIES: The project will continue for another two years in order to accomplish the defined objectives.

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LEACHING OF BROMIDE AND ATRAZINE IN RIDGE-FURROW SYSTEM UNDER FURROW AND SPRINKLER IRRIGATION

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PROBLEM: High nitrate levels in groundwater in the Great Plains have been attributed to nitrogen fertilizer applications on cropland. Alternative soil management techniques must be found to allow the use of nitrogen fertilizers on crop land and yet minimize adverse environmental effects. Leaching of pesticides must also be minimized.

APPROACH: An irrigation-nitrogen placement experiment for irrigated corn production was established in 1994 at ARDEC (Agricultural Research, Demonstration, and Education Center) at Ft. Collins, Colorado. Two irrigation water placements, alternate furrow irrigation (AF) and every furrow irrigation (EF), were tested to determine the plant use of the nitrogen fertilizer and nitrate leaching in the soil. Bromide and atrazine ware used to investigate the leaching with alternate furrow irrigation, every furrow irrigation, and sprinkler irrigation in both 1995 and 1996. Chemicals were applied in June. The first soil samples were taken in July and the second soil samples were taken in October of both 1995 and 1996 (bromide only).

RESULTS: Bromide results have been analyzed. The bromide recovery rate is low. Overall recovery rate was only 52%. The recovery rate was 53.5% in 1995 and 50.5% in 1996. In 1995, bromide was recovered about 54% for alternate furrow irrigation, 71% for every furrow irrigation, and only 37% for sprinkler irrigation. Similarly, in 1996, bromide was recovered about 56% for alternate furrow irrigation, 61% for every furrow irrigation, and only 35% for sprinkler irrigation. The two-dimensional water-corn model was modified to simulate bromide exchange between mobile and immobile (aggregates) regions. Bromide was initially placed in aggregates and slowly released into mobile soil water. With this approach, the simulated bromide breakthrough curve agrees with the measured date better than without aggregates effect.

FUTURE PLANS: More bromide leaching simulations will be continued for part of 1995 irrigation plans and all 1996. Different irrigation schedules will be simulated theoretically to examine the leaching. Atrazine movement will also be simulated for 1995.

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DEVELOPMENT OF GPFARM VISUALIZATION MODULE

M.J. Shaffer, M.K. Brodahl, J.C. Ascough II and B. Vandenberg

PROBLEM: A whole farm analysis using GPFARM DSS generates a large quantity of complex information about a farm. The usefulness of this information to any one user is dependent on the user's ability to identify the information of importance to their problem, to obtain an appropriate summarization of that information, and to present a summarization that is easily understood by the user.

APPROACH: "A picture is worth a thousand words" is a well known rule of thumb and we have chosen to emphasize the summarization of GPFARM results in a visual format along with the tabular summaries generated by the program. This visual format should present data in a variety of graphical formats including charts and maps. The user should be able to select the data to summarize, to select how those data are summarized (e.g., total, average, minimum, etc.), to select the conditions over which that data is summarized, and to choose the format for summarization. In addition the user should be able to obtain a general summary over the whole farm and then be allowed to explore the details of that information.

RESULTS: A prototype version of the GPFARM visualization module has been completed and is included in the beta release of GPFARM. Software was developed for a GPFARM specific data post processor, a GPFARM independent system for managing this data for visualization, and a GPFARM independent system for visualization. The post processor "organizes" the data from a GPFARM simulation for use in the visualization software. The visualization software is programmed in object oriented C++. It consists of a flexible system for input of data in a programmer specified format, a system for allowing user specified query and summary of annual or aggregated management unit data, a charting system for the summarized data, and a Visual C++ user interface.

FUTURE PLANS: Summarization of GPFARM results will be re-visited during and after beta-test results to identify what data are needed by the users for interpretation of GPFARM results and the appropriate summary of these data. The query system needs to be expanded to handle within-annual data; data that are reported at the field, subfarm, and farm levels (in addition to the management unit level data); and the economic data. The system also needs to be expanded to work with quantitative as well as categorical query of the data. The graphics portion of the system needs to incorporate map graphics which can interact with the charting portions of the visualization. Finally, the interface for the visualization portions will be refined and improved based on beta-test results and development of additional visualization capabilities.

DEVELOPMENT OF GPFARM SCIENCE SIMULATION MODULE

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G.S. McMaster and L. Deer-Ascough[1].

PROBLEM: A need exists for an integrated modeling package capable of simulating agricultural production systems in a whole farm setting using time and spatial scales suitable for the objectives of the GPFARM decision support system. Major components include crop and animal production, soil water and solute transport, nutrient cycling, evapotranspiration, tillage and residue effects, surface runoff and erosion, pesticide interactions, and weed management. The system model must be capable of simulating many different crops (including animals) in a multi-year rotational system for both irrigated and dryland conditions.

APPROACH: Existing technology and submodules were selected that are approximately suitable for the project objectives. Modifications and adaptations are being made to make these modules more appropriate for GPFARM. Simulation modules written in FORTRAN and Visual Basic have been integrated to operate from a control framework written in C++. The objective is to produce a suitable package capable of simulating soil-plant-animal processes for individual, but interacting management units in fields across a farm.

RESULTS: A beta version of the GPFARM science simulation package was completed that combines FORTRAN and Visual Basic modules at the calculations level with an object-oriented C++ framework that manages the overall system integration. A major revision to the animal module was made to allow for both animal and range forage production. Refinement and testing was done to the surface residue and crop growth modules. A new weeds module was introduced that combines the latest technology in that area. The C++ framework was extended to support management additions of fertilizers, residues, animals, and irrigation. Framework support was developed and refined for output databases that link with the GPFARM DSS visualization user interface. Event framework implementation modules were tested that allow introduction of management events that are scheduled based on user-supplied rules and a defined state of the system.

FUTURE PLANS: The beta version will be further evaluated and upgraded to Release Version 1.0 suitable for evaluation and use by a range of users. This includes refinement and testing of the revised animal module, addition of revised water and wind erosion modules, addition of a rule-based configuration for irrigation scheduling, and additional testing of all science modules. Other future plans call for expansion of the nutrient module to include phosphorus and potassium and incorporation of the full rule-based management system

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DEVELOPMENT OF GPFARM RULE-BASED EVENTS MODULE

M.J. Shaffer and M.K. Brodahl

PROBLEM: Most agricultural operations are run according to guidelines or rules that are established by each producer and are specific for a particular farm. To make effective use of emerging technology, producers and their crop consultants need to enter these rules into computerized decision support systems and then modify the rules as required. This dynamic linkage between the actual farming system and the computer is essential for representative feedback from the decision support systems.

APPROACH: We are developing a comprehensive rule-based management system for agricultural decision support systems that allows simulated management events to occur in response to producer-defined rules and to changes in the soil-crop system over time and space. Existing attempts at rule-based management involve limited extension of fixed management dates in response to environmental conditions, or involve rules for implementing limited management events such as fertilizer applications. Our system provides a simple, English-based rules language, a rules development editor, and software to parse and interpret these rules and provide linkages to application simulation software packages such as GPFARM, NLEAP, and others.

RESULTS: Considerable progress was made in testing and refinement of the rule-based system. Agricultural producers in eastern Colorado were interviewed to capture their on-farm management rules for incorporation into the rule-based system and subsequent testing. Rules were developed for wheat-corn-fallow, wheat-corn-millet-fallow, and wheat-fallow rotations, and then linked to the GPFARM simulation framework. Simulation results for rule-based management events representing several crop rotation cycles indicated that the rule-based system correctly generated expected management events and their associated attributes within the specified time windows and in the correct sequence. Multiple events within the same day were also handled properly and in the correct order. As expected, generated events tended to fall on slightly different calendar dates in each rotation cycle due to climate variability and other soil-crop interactions.

FUTURE PLANS: Our rule-based system will be used to incorporate irrigation scheduling into GPFARM as part of release version 1.0. The entire rule-based system will be incorporated into GPFARM in the 2nd phase. We will continue to interview producers in eastern Colorado and incorporate their on-farm management rules into our system. Based on these results and other work, refinements will be made in the rules editor to make it more easily used by producers and consultants, and in the interpreter code to allow it to handle more complex management systems.

DEVELOPMENT OF GPFARM SURFACE RESIDUE DECOMPOSITION MODULE

M.J. Shaffer, M. Vigil[1] and R. Anderson[1]

PROBLEM: The dynamics of crop residues on the soil surface are extremely important to agriculture from the standpoints of water availability and conservation, nutrient cycling and availability, erosion control, maintenance of soil organic matter, weed control, and soil temperature management. Development of the GPFARM decision support system (DSS) required a surface residue decomposition model that combined the basic processes for standing-stem persistence, residue mass decomposition, and inorganic nutrient cycling and fate on the soil surface.

APPROACH: The objective of this research was to develop a comprehensive yet efficient modular model for surface crop residue decay that links stem persistence with residue mass decay and nutrient cycling on the soil surface and can be coupled with other process submodels for use in GPFARM. Long-term field data for surface residues are available from the Akron ACR plots. Additional data have also been collected at Akron for standing-stem persistence. This information together with existing nutrient simulation code from the NLEAP model are being used to develop and test this expanded model.

RESULTS: A comprehensive surface residue decomposition model has been assembled for use in GPFARM that simulates decay of standing dead and flat-lying residues, as well as nutrient transformations of mineral N on the soil surface. The model provides for multiple pools of standing dead and flat-lying residues that track each year's residue input from harvest until the residue has decayed to form humus, or has been incorporated into the soil or otherwise removed or lost from the soil surface. Standing-stem fall down is transferred to the flat-lying residue pool at periodic intervals. The model also incorporates processes and cycling associated with NH_4 and NO_3 on the soil surface that are located within both residue-covered and bare soil areas. Processes included are decay of residues, nitrification, denitrification, and ammonia volatilization. Decay of manures and other organics such as sewage sludges is also handled by the surface residue module. Preliminary calibration of the model was done using data from the literature and from Akron.

FUTURE PLANS: The model is being thoroughly tested and validated using field data from the Akron plots and elsewhere.

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SIMULATION OF REGIONAL SOIL NITROGEN GAS FLUXES USING NLEAP

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PROBLEM: Concern regarding the global climate change and potential of health and environmental effects of changing atmospheric trace gas concentrations has been increased. Simulating emissions of nitrogen gases from soils as a function of soil properties, climate, crop production, and management practice can be important in the understanding of the role of terrestrial ecosystems played on the global climate change, in assessing of environmental impact of agricultural production, and in determining the natural resources using and management strategies.

APPROACH: Effective evaluation of alternative management strategies to control global warming requires tools for simulating emissions of nitrous oxide (N_2O) from soils across a range of soil property, weather, and management inputs. We modified the nitrification and denitrification submodels of the Nitrate Leaching and Economic Analysis Package (NLEAP) model to simulate daily N_2O emissions and demonstrate the utility of using the NLEAP gas model in conjunction with a GIS to estimate soil emissions of N_2 and N_2O gases.

RESULTS: Nitrification and denitrification submodels of NLEAP were modified to simulate daily N_2O emission rates. The results indicated that temperature, rainfall events, soil physical and chemical properties, fertilizer application and crop varieties are all important factors which govern N_2O emission processes in soils. The statistical comparison of field measured and model simulated values of N_2O emission rates suggested that the trends and magnitudes of simulated nitrogen gas using the modified NLEAP model were consistent with results obtained from the field experiments. The NLEAP-GAS model was developed in conjunction with a Geographical Information System (GIS) to predict N_2O emissions from a 13,000 ha agricultural area in Northeast Colorado. The input and simulation capabilities of NLEAP provide emphasis on the influence of agricultural management such as tillage, irrigation, fertilizer and manure applications, and cropping practices. Spatial distribution of N2O emissions across landscapes and regions reflected that clay loam soil produced higher N_2O as compared to clay, loam and sandy soils. The study indicated that spatial distribution of simulated N_2O emissions was satisfactorily explained by spatial variability of agricultural management and spatial variation in soil physical and chemical properties.

FUTURE PLANS: The research will emphasize simulation and field experiments of N_2O emissions on a variable nitrogen treatments, animal manure applications, tillage treatments and irrigation management under different soil types.

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MODIFICATION OF NLEAP FOR FERTILIZATION RECOMMENDATIONS

M.J. Shaffer, G. McNabb[1] and M.K. Brodahl

PROBLEM: J.R. Simplot, Inc. wants to develop improved methods for their dealers to make fertilizer recommendations to customers.

APPROACH: A CRADA was developed between USDA-ARS, Fort Collins, CO and J.R. Simplot Company, Inc., Pocatello, ID. Simplot is developing the customer user interface and ARS is adapting the NLEAP model for fertilizer recommendations.

RESULTS: An innovative interface design was developed suitable for use by Simplot fertilizer dealers. The design emphasizes simplicity of use by the operator along with appropriate tracking of nutrient availability and uptake, crop growth, and nitrate leaching during the growing season. It steps the model day by day through the season allowing for individual entry of crop events such as a rain event, an irrigation event, a chemical application event, and others. The interface design is being implemented in Microsoft Visual C++ 5.0 using ActiveX and COM technology as much as possible and is compatible with the NLEAP driver framework and simulation code described below developed in C++ and Fortran. The NLEAP Fortran process simulation code from DOS NLEAP version 1.3 was modularized for use as a separate package callable from a range of driver packages written in C++, Fortran, Java, and other languages. In addition, the NLEAP water flow and solute transport subroutines were included along with the NLEAP ET and NRCS curve number methods for surface runoff. The nutrient modules now simulate the carbon and nitrogen cycle both within the soil profile and on the soil surface. A crop growth module was developed that extends the previous NLEAP fixed growth curve method to allow crop response to temperature, water, and nutrient stress. The technique begins with an ideal maximal curve for each crop or crop variety and modifies the dry matter production and crop yield curves over time during the growing season depending on temperature, nutrient, and water stresses. A C++ object-oriented framework driver module was developed to (1) manage NLEAP input and output operations for a series of interacting management units (MUs), (2) control the simulation for each day and soil horizon, (3) provide for maintenance and testing of water and nutrient mass balance, and (4) provide daily output for graphical and other purposes.

FUTURE PLANS: The Simplot and ARS work completed to date under this CRADA will be merged into an operational prototype and field tested over a range of crops and nutrient management conditions.

[1]J.R. Simplot, Inc., Pocotello, ID

ROOT DISTRIBUTION UNDER ALTERNATE FURROW IRRIGATION

R.H. Skinner, J.D. Hanson and J.G. Benjamin[1]

PROBLEM: Alternate furrow irrigation of corn, with fertilizer placement in the non-irrigated furrow, provides a potential means of reducing nitrate leaching and groundwater contamination. Lack of root growth in the non-irrigated furrow, however, may limit N uptake. Separating fertilizer from the water supply may also reduce N uptake and plant growth because N supply to the root system in high productivity systems relies heavily on mass-flow transport in the soil solution. Several studies have shown that roots tend to proliferate in areas where water and/or nutrients are found in abundance, however, the effects of spatially separating water and nutrients within the soil profile on root distribution have not been investigated.

APPROACH: Water and N were applied in a 2x2 factorial with every furrow vs. alternate furrow irrigation, and furrow vs. row fertilizer placement. Corn roots and shoot were sampled four times during each of two growing seasons, at V6-V9, V12-V16, R1 and R5-R6 in plots fertilized with 15N-labeled fertilizer. Soil cores for root distribution, root nitrogen concentration, and soil water and nitrate determinations were taken in 30 cm increments to a depth of 120 cm from a 3 x 3 sampling grid centered over single corn plants which were harvested for shoot biomass and N content.

RESULTS: Maximum root biomass was observed at the R1 growth state. At R1 the main effects for irrigation treatment and fertilizer placement were not significant. Fertilizer by irrigation interactions affected root distribution but not total root biomass. When the fertilized furrow was not irrigated, 19% of the roots were in the fertilized furrow, 16% were in the irrigated but non-fertilized furrow, and 65% were beneath the row. Adding water to the fertilized furrow increased its percentage of the total root biomass to 25% at the expense of the non-fertilized furrow (13%) and row (62%). The greatest redistribution of root growth occurred under alternate furrow irrigation when fertilizer was placed in the row. With this treatment 28% of the roots were found in the dry furrow, 10% in the wet furrow, and 62% in the row. Under every furrow irrigation and row fertilizer placement, 72% of the roots were beneath the row. The remainder was distributed evenly between the two furrows. Alternate-Furrow irrigation increased fertilizer N uptake over every-furrow irrigation during reproductive growth when fertilizer was placed in the furrow.

FUTURE PLANS: One manuscript remains to be written, then this project will be completed.

[1]USDA-ARS, NPA, Central Great Plains Research Station, Akron, CO

CARBON AND NITROGEN REMOBILIZATION FOLLOWING DEFOLIATION

R.H. Skinner, J.A. Morgan[1] and J.D. Hanson

PROBLEM: Following defoliation, both photosynthesis and N uptake can cease or be greatly reduced for a period of time. Initial shoot regrowth then depends on reserve N and C stored in root and crown tissue. We are interested in determining the relative importance of stored C and N in the regrowth process, which specific reserves are remobilized, how soil N concentration and atmospheric CO2 affect reserve remobilization, and how the re-establishment of root:shoot ratio following defoliation can best be modeled.

APPROACH: A forage legume (alfalfa), C3 grass (western wheatgrass), and C4 grass (blue grama) were grown in growth chambers with two atmospheric CO2 concentrations and two soil N concentrations to provide a range of C and N storage levels in crowns and roots, as well as a range of external supply conditions for regrowth. Four growth chamber experiments will be conducted (two at ambient and two at elevated CO2). Following defoliation, sequential harvests were made at 0, 4, 7, 10, 14, and 20 d, and plants separated into root, crown and regrowth tissue. Total dry weight was determined for each tissue, and N pools were partitioned into buffer-insoluble proteins, buffer-soluble proteins, and low molecular weight N compounds (amino acids, NO3, etc.). Carbon was partitioned into structural dry matter, water soluble carbohydrates, and starch. Nitrogen and carbon remobilization and uptake were determined by changes in the respective pool sizes of each tissue. Results will be compared with several root:shoot partitioning models to determine which best describes the regrowth process.

RESULTS: Regrowth was strongly, and negatively, correlated with whole-plant relative growth rate during the first 4 d after defoliation. Thus, regrowth was greatest in plants that were able to quickly and completely shut down partitioning to crowns and roots. Elevated CO2 increased TNC remobilization in alfalfa, reduced remobilization in blue grama and had no effect on western wheatgrass. Nitrogen fertilization had little effect on TNC remobilization except for blue grama grown at elevated CO2 where remobilization was reduced in the high N treatment. Nitrogen deficiency and elevated CO2 generally reduced N remobilization rate and the contribution of remobilized N to shoot regrowth. Elevated CO2 also reduced the time needed for TNC and N reserves to re-accumulate to pre-defoliation levels, suggesting that defoliation frequency could be increased as atmospheric CO2 increases.

FUTURE PLANS: Three manuscripts will be written (two currently in progress), which will then finish this project.

[1]USDA-ARS, NPA, Rangeland Resources Research Unit, Fort Collins, CO

PLANT/SOIL CARBON & NITROGEN PARTITIONING AS AFFECTED BY GRAZING AND SOIL MOISTURE

R.H. Skinner, J.D. Hanson, G.L. Hutchinson[1], J.A. Morgan[2], J.D. Reeder[2] and G.E. Schuman[2]

PROBLEM: Preserving the stability of rangeland soils requires that degradation of soil C and N levels be prevented. Adjusting grazing pressure is one of the few options available for range managers to influence plant productivity and soil health, while soil moisture availability is one of the primary constraints on plant production in these systems. This study examines how the interaction between water availability and grazing pressure affects plant production and the partitioning of C and N to shoots, roots, and soil organic pools.

APPROACH: Small plots were established in pastures at the High Plains Grasslands Research Station near Cheyenne, Wyoming, that had experienced either heavy grazing or had been ungrazed for 14 years. Half of the plots received between 0 and 18 mm of supplemental irrigation weekly, depending on rainfall during the previous week. Irrigation treatments were designed to even out the normal fluctuations in precipitation that usually occur during the summer without providing unreasonably high total amounts of water. Thirty-centimeter deep soil cores, with their accompanying aboveground plant growth, were collected in late May, early August, and early November. Aboveground plant materials were partitioned based on species type (C3 grasses, C4 grasses and forbs) and tissue condition (green, recently senesced, crowns and litter). Roots were collected from 0-5, 5-15 and 15-30 cm soil depths. Data collected include plant biomass and C and N content, soil moisture, texture, bulk density, total C and N, and inorganic N.

RESULTS: The summer of 1997 was one of the wettest on record, yet there was still a 5 wk period where no rainfall was received. Irrigation treatments increased aboveground production at the August harvest (shortly after the 5-wk drought), but had only a small effect on root growth. The greatest increase (66%) was in the ungrazed treatment where C3 grasses made up 90% of the total grasses. Irrigation increased production by 44% in the grazed plots which had a more even mixture of C3 (67%) and C4 (33%) grasses at the August harvest. Root production was greater in the grazed compared with the ungrazed plots, especially under irrigation. No significant difference in aboveground production existed between the two grazing treatments, but species composition was affected. Excluding grazing increased C3 production while C4 growth was promoted in the grazed plots.

FUTURE PLANS: This project will be continued during the summer of 1998.

[1]USDA-ARS, NPA, Soil, Plant, Nutrient Research, Fort Collins, CO
[2]USDA-ARS, NPA, Rangeland Resources Research Unit, Fort Collins, CO and Cheyenne, WY

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RANGELAND RESOURCES RESEARCH UNIT

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5409-11000-001-04S	Responses of rangeland grasses to C02 and herbivory
5409-12630-001-00D	**Plant and animal responses to environment and management**
5409-12630-001-01R	Seed treatment and sagebrush seedling vigor
5409-12630-001-06R	Evaluation of reclamation methods to mediate bentonite spoil sodicity
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MISSION STATEMENT

The research mission of the Rangeland Resources Research Unit is to develop an understanding of the interrelations of the basic resources that comprise rangeland ecosystems. Research is directed toward the development of science and technology that contributes to enhanced forage and livestock production and sustainable, productive rangelands in the Central Great Plains.

TECHNOLOGICAL TRANSFER

L.W. Griffith hosted the Colorado Nurserymen's Association tour of the HPGRS arboretums, August 14, 1997.

G.E. Schuman attended the Society for Range Management meeting and presented a paper on management strategies for CRP lands, Rapid City, SD, February 17-21, 1997.

Pam Freeman and G.E. Schuman judged biology and physical science sections of the District Science Fair, Laramie County Schools, Cheyenne, WY, March 15, 1997

G.E. Schuman attended and presented rangeland C dynamics research to the Wyoming Soils Committee workshop sponsored by the Wyoming State NRCS, Casper, WY, May 6-7, 1997.

G.E. Schuman hosted Mr. Lochlin Ingram, Ph.D. student working in rangeland C and N dynamics, University of Western Australia, Nedlands, W.A., May 30-June 8, 1997

G.E. Schuman attended the Int'l Grassland Congress, Winnipeg, Manitoba, June 9-14, 1997.

G.E. Schuman hosted Mr. Mark Ritchie, Manager, Australian Pastoral Corp, Queensland, Australia, and organized his visit with the Research Unit, local ranchers, Forest Service and Park Service staff, June 19-25, 1997.

J.A. Morgan and G.E. Schuman hosted Mr. Charles Probandt, Vice-Chair, Nat'l Woolgrowers Assoc., San Angelo, TX, who came to visit about the RRRU's research program and discuss the need for multi-species grazing research and range research in general, July 23-24, 1997

G.E. Schuman served as co-chair of the Central Plains Dryland Agricultural Systems Group and hosted this group's summer meeting and a tour at the HPGRS and the Univ. of Wyoming Archer Research and Extension Center, which included university and ARS scientists from Nebraska, Colorado, Kansas, Oklahoma and Wyoming, August 5, 1997.

G.E. Schuman participated in the Western Coordinating Committee-21 meeting and discussed research relating to rangeland rehabilitation, and toured proposed and historic gold mining areas in Bear Tooth Mountains, Cooke City, MT, August 18-22, 1997

L.W. Griffith, D.T. Booth and E.M. Taylor, Jr. judged the science fair at Pioneer Park Elementary School, February 21, 1997.

G.E. Schuman and J.A. Morgan attended and were chairman of two subdivisions of the ARS Global Change Program review meeting, Temple, TX, September 22-26, 1997. We also discussed CO2 flux network findings and research plans.

G.E. Schuman lectured to a graduate level Restoration Ecology class at the University of Wyoming, October 16, 1997.

G.E. Schuman, J.D. Reeder, J.A. Morgan and E.M. Taylor attended the American Society of Agronomy/Soil Science Society of America meetings in Anaheim, CA. Schuman, Morgan, and Reeder presented papers on the carbon and nitrogen dynamics of grazed rangelands, October 27-31, 1997.

G.E. Schuman and J.A. Morgan presented teamwork/partnershiping efforts in our rangeland research program at the Riley Memorial workshop. They were invited as one of four groups representing the Western United States to make this presentation, Reno, NV, November 4-6, 1997.

G.E. Schuman, D.T. Booth and S. Clapp attended the Wyoming Section, Society for Range Management meeting in Casper, WY, November 12-13, 1997. G.E. Schuman chaired a technical session of the meeting.

G.E. Schuman and D.T. Booth presented seminars on grant funded research at the Abandoned Coal Mine Land Research Program seminar, G.E. Schuman also serves on the Steering Committee for this research grant program, Gillette, WY, November 18-19, 1997.

G.E. Schuman attended the Grazing Lands Forum, Washington, DC, as the representative for the Soil Science Society of America, December 3-5, 1997

Pam Freeman served on the World Wide Web AG Team, the 4-H Laramie County Fair Superintendent - Natural Resources Projects, 4-H Leader, and Laramie 4-H Council - District Representative,

Pam Freeman talked to Dildine 4th graders about Range Management, handed out range comic books; and discussed soil and rangeland being a natural resource, 25 students, April 10, 1997.

Pam Freeman demonstrated soil and plant projects to the GS Brownies, talked about how plants are good for soil and soil is important for plants to grow, 10 participants, March 5, 1997.

Pam Freeman gave a presentation at the 1997 Expanding Your Horizons Workshop, introduced 5-12 graders to careers in ARS, and had hands on soil activities, 300 participants, March 13, 1997.

Pam Freeman gave a tour of the greenhouse to a group from Magic City Enterprises and talked about the research being done at the Station, 8 participants, July 12, 1997.

R.H. Hart presented a talk "Plant community responses to livestock grazing in northern mixed-grass prairie" at the Montana/Wyoming Range Management Workshop, "Ecology and Management of Grazing by Large Herbivores," Sheridan, WY, January 8, 1997.

R.H. Hart attended the Society for Range Management annual meeting, Rapid City, SD, February 16-21, 1997, and presented papers "Can we broaden the rangeland audience without denying our grazing heritage?" (first presented at the 1996 meeting) and "Rangelands of the Great Plains before European settlement."

R.H. Hart attended the ARS Southern Plains Area Leadership Conference, Austin, TX, February 24-16, 1997, as Theodore Roosevelt and presented a talk on conservation of rangelands and other natural resources.

R.H. Hart attended a planning session of Rangeland Ecosystem Science Dept., Colorado State Univ., Fort Collins, CO, February 28, 1997.

R.H. Hart lectured to 24 students of the "Wildlife Habitat & Ecology" class, Rangeland Ecology & Watershed Management Dept., Univ. of Wyoming, Laramie, WY, March 11, 1997.

R.H. Hart judged the Cheyenne School District #1 Science Fair, Cheyenne, WY, March 15, 1997.

R.H. Hart judged agriculture-related presentations at the Wyoming History Day, Casper, WY, April 14, 1997.

R.H. Hart gave an HPGRS tour to 19 students of "Rangeland Ecosystems" class, Colorado State Univ., April 19, 1997.

R.H. Hart attended a planning meeting of Laramie County Conservation District, Cheyenne, WY, April 23, 1997.

R.H. Hart attended the 18th International Grassland Congress, Winnipeg, Manitoba, and Saskatoon, Saskatchewan, June 8-19, 1997, presenting two poster papers, "Animal-plant interactions in an *Atriplex canescens*-dominated community browsed by cattle" and "*Atriplex canescens* impact on understory vegetation under three seasons of grazing."

R.H. Hart visited with Amin al-Jundi and Haitham Khaddour, rangeland managers with World Bank, Damascus, Syria, June 30, 1997, on management of grazing lands and rangeland nature reserves.

R.H. Hart presented a talk "Rangelands of the Great Plains before European settlement," in a lecture series sponsored by Laramie County Conservation District, Cheyenne, WY, July 10, 1997.

R.H. Hart met with NRCS Grazing Technology Transfer Teams from Cheyenne; Akron, CO; and Mandan, ND, at Cheyenne, WY, August 27, 1997.

R.H. Hart presented the seminar "Rangelands of the Great Plains before European settlement" to about 50 students and faculty of Environmental, Organismic, and Population Biology Dept., Univ. of Colorado, Boulder, CO, September 26, 1997.

R.H. Hart gave an HPGRS tour to 23 students of "Rangeland Ecosystems and Grazing Management" class, Univ. of Wyoming, Cheyenne, WY, October 6, 1997.

R.H. Hart gave an HPGRS tour (Oct 7) and lectured (Oct 9) to 9 science class students on rangeland issues, High School III, Cheyenne, WY, October 7 & 9, 1997.

R.H. Hart gave an HPGRS tour for 17 ranchers and farmers from Chile, discussed research on windbreaks, soil conservation, and grazing management, Cheyenne, WY, October 10, 1997.

R.H. Hart participated in discussions with Guy Midgely, a visiting scientist from South Africa, Cheyenne, WY, October 15, 1997.

R.H. Hart gave an HPGRS tour for 10 members of Southeast Wyoming Chapter, Society of American Foresters, Cheyenne, WY, October 23, 1997.

R.H. Hart discussed aerial photography of HPGRS and CPER with Jerry Ritchie from Hydrology Laboratory, USDA-ARS, Beltsville, MD, October 30, 1997.

Gary Frasier conducted water harvesting technology workshops for 10 technicians from ICARDIA in Matrouh, Egypt, March 2-11, 1997.

Gary Frasier discussed research at CPER to 25 visiting foresters of the International Society of Forestry, September 11, 1997.

Jean Reeder responded to a request from Cynthia Hartman, Ft. Collins, CO, for information on alternatives to wheat-fallow cropping for her parent's Kansas farm, July 12, 1997.

Jean Reeder cooperated with a request from Nan Rosebloom, a research assistant at NCAR, Boulder, CO, for literature, methods information, and advice dealing with soil aggregation, April 15, 1997.

Jean Reeder cooperated with a request from a soil scientist Tim Carney, NRCS, for literature and advice on dealing with disposal of poultry manure on grasslands, July 14, 1997.

Jean Reeder responded to a request for information and advice from Carolyn Schulders, Consultant, San Francisco, CA, who is working on stabilizing landslide areas along California coastal highways, May 17, 1997.

Jean Reeder responded to request from Kim Sum Quay, Ft. Collins, CO, for information on alternatives to wheat-fallow cropping and terracing of fruit orchards in Hong Kong, December 10, 1997.

J.A. Morgan led Ecosystems Dynamics Group at the ARS Global Change Workshop in Temple, TX, September 23-25, 1997, which was conducted for the purpose of exchanging information and ideas among ARS scientists presently working on global change and included about 50 participants.

J.A. Morgan was an invited speaker at the Western Region Workshop "Productivity and Conservation: Working Toward Common Goals," Reno, NV, November 4-5, 1997, and was one of four speakers who discussed the collaborative projects and interactions of the Rangelands Resources Research Unit with our customers and colleagues, which included about 50 natural science professionals from various state and federal agencies.

J.A. Morgan NCEAS (National Center for Ecological Analysis and Assessment) "Net Primary Production Workshop," Santa Barbara, CA, December 10-14, 1997, and was invited to participate in a workshop to develop strategies for scientists to estimate primary production, including below ground plant growth, in the world's grassland, boreal forests, and tropical forests, which included twenty participants.

J.A. Morgan was the invited speaker at the Shortgrass Steppe Symposium, Ft. Collins, CO, January 14, 1997, which included approximately 80 participants, and discussed collaborative research of the group conducting open-top chamber CO_2 enrichment studies on the shortgrass steppe.

J.A. Morgan conducted a tour of current global change research being conducted at the Central Plains Experimental Range for the Environmental Educational Academy, CPER, CO, June 18, 1997, which included 30 participants. The Academy is a summer course offered for Colorado science teachers to let them interact with practicing scientists and to discuss some of the latest environmental research projects.

J.A. Morgan served as an outside expert reviewer for a Ph.D dissertation "Responses of C_3 and C_4 Panicum grasses to CO_2 enrichment," at Hawkesbury, Australia, August, 1997, which included 8 participants.

J.A. Morgan reviewed research grants for funding agencies and manuscripts for several scientific journals, continuous throughout the year, 1997.

J.A. Morgan authored an article on global changes research, including text and photographs that was printed in July, 1997, as an edition of the ARS Agricultural Research Magazine, Washington, D.C., and which discussed our research on atmospheric CO_2 enrichment and its effects on native grasses of the shortgrass steppe.

J.A. Morgan's research was featured in a front-page article in the Coloradan Newspaper, Ft. Collins, CO, September 22, 1997, entitled "Team studies warming impact on crops." The article discussed in detail global change research being conducted by myself, Arvin Mosier and collaborators at Colorado State University.

J.A. Morgan was interviewed October 24, 1997, along with Arvin Mosier and members of our research teams about our research in global change by the KUSA TV Station from Denver, CO. The newsclip was presented on the Evening News.

CARBON AND NITROGEN BALANCE IN GRAZED SEMI-ARIS RANGELANDS

J.D. Reeder, G.E. Schuman, J.A. Morgan, D.R. LeCain and R.H. Hart

PROBLEM: Rangeland grazing management strategies affect forage production, plant community structure, soil chemical and physical properties, and the distribution and cycling of carbon (C) and nitrogen (N) within the plant-soil system. A better understanding of how grazing management affects rangeland C and N dynamics should improve our understanding of the system and help develop management technologies that ensure sustainability of our rangelands.

APPROACH: This study was conducted at the Central Plains Experimental Range (CPER) near Nunn, CO, on a semi-arid shortgrass steppe. Soil and plant samples were collected along transects in pastures that have been heavily-, lightly- or non-grazed for the past 55 years. Samples were collected at peak production adjacent to m^2 plots used to characterize CO_2 exchange rates (see other report). The soil profile (0-60 cm) and vegetation (roots, aboveground litter, standing dead, and live biomass by plant category) were evaluated for C and N to determine the influence of these management strategies and stocking rates on C and N cycling and distribution in the plant-soil system.

RESULTS: Long-term heavy grazing of the shortgrass steppe has resulted in a significant increase in C in the 15-30 cm depth of the soil profile, but long-term grazing at either stocking rate has not significantly affected the content or distribution of soil N. The increase in soil C content was due in part to a redistribution of system C caused by a grazing-induced increase in warm season grasses, which transfer more photosynthate below ground than do cool season grasses. Heavy grazing also resulted in a higher apparent annual shoot turnover, thus stimulating the cycling of aboveground C into the soil. The response of soil C and N to grazing was less pronounced in this shortgrass steppe than in a previously studied mixed grass prairie. The shortgrass steppe, dominated by warm season grasses, is more resistant to disturbance by grazing than the mixed grass prairie which is dominated by cool season grasses.

FUTURE PLANS: The soil data has been summarized and presented at a national meeting. Vegetation data are being summarized to evaluate the content and distribution of C and N in the various plant components. A manuscript reporting the C and N balance of the system will be prepared. This phase of the rangeland C and N cycling and balance research as affected by grazing is complete.

USING ISOTOPES TO EVALUATE CARBON AND NITROGEN DYNAMICS IN A MIXED-GRASS RANGELAND

G.E. Schuman, G.L. Hutchinson[1], J.D. Reeder, H. Skinner[2], J.A. Morgan, R.H. Hart and D.R. LeCain

PROBLEM: Livestock management has been shown to affect C and N dynamics of native rangeland ecosystems. However, questions of magnitude and time-frame are important in assessing how CO_2 and N sequestered by the plant community of variously managed ecosystems affects system dynamics.

APPROACH: Field studies employing stable isotopes were initiated in 1997 to investigate (1) soil organic matter dynamics as a function of grazing intensity, C_3 and C_4 species composition, and water availability, and (2) the effect of various factors of C and N partitioning within the soil-plant system. Sixty-six microplots in each of 3 grazing treatments (continuous light, continuous heavy, and non-grazed) were established by pushing PVC cylinders (25 cm diameter by 33 cm long) into the soil. $^{13}CO_2$ and $K^{15}NO_3$ were applied during active early spring growth. At various phenological stages of the primary species, 6 cylinders were removed from each grazing treatment. Five sets of cylinders were removed in 1997. Aboveground biomass was separated into live C_3 and C_4 plants, standing dead plants, crowns, and litter. The soil was separated into 0-5, 5-15, and 15-30 cm increments, and all roots removed from the soil. To determine the effects of soil spatial variability and soil water on the data from the labeled cylinders, small rectangular plots were established next to the cylinders in the non-grazed and continuous heavy grazed treatments. Additional water was applied weekly to half of the rectangular plots, which were sampled the week after the cylinders were removed and separated into similar soil and plant components. All plant material is being analyzed for carbohydrates and total and isotopic C and N. Soil fractions are being analyzed for water content, bulk density, total and isotopic C and N, total and isotopic NH_4^+ and NO_3^-, microbial biomass, and mineralizable C and N.

RESULTS: Analyses are incomplete for the 1997 sample collection year at this time; therefore, no results are available.

FUTURE PLANS: This study will be continued through 1999. Four sets of cylinders will be removed and processed in 1998 and two sets in 1999.

[1]Soil-Plant-Nutrient Research Unit, Fort Collins, CO;
[2]Great Plains Systems Research Unit, Fort Collins, CO

CARBON AND NITROGEN DYNAMICS OF MARGINAL CROPLANDS RESEEDED TO GRASS COMMUNITIES

G.E. Schuman, J.D. Reeder, R.A. Bowman[1] and E.M. Taylor, Jr.

PROBLEM: A better understanding of the factors controlling soil organic matter formation and its activity is necessary to protect and restore the soil quality of marginal, highly erodible cropland.

APPROACH: Field sites were established in 1987 at Egbert (southeastern), Keyline (east central), and Arvada (northcentral), Wyoming. Treatments included: (1) continued wheat-fallow cropping of marginal land, (2) plowed native grassland cropped to wheat-fallow, (3) grass established on long-term wheat-fallow marginal cropland, and (4) native grassland. Soil and vegetation were assessed annually from 1987-1995. Soil were assessed for C and N and vegetation production and C and N were assessed to enable development of a C and N budget for these treatments.

RESULTS: In 1997 vegetation production data were collected on the native grassland and reestablished grassland treatments. The wheat-fallow plots were fallowed and winter wheat planted in 1997. A manuscript comparing the initial 1987 soil C and N levels to those observed in 1993 after three wheat-fallow cycles was prepared. Six years after plowing the native rangeland and initiating wheat-fallow, both the total and potential net mineralized C and N in the surface soil had decreased to levels observed after 60+ years of cultivation. Five years after establishing grass on the 60+ wheat-fallow cropland (sandy loam soil) both total and potential mineralized C and N in the surface soil had increased to levels equal or greater than those observed in the A horizon of the native rangeland. On the reestablished grass plots on the clay loam site, significant increases in the total organic C were observed only in the surface 2.5 cm and total organic N had not changed.

FUTURE PLANS: This project will be terminated in 1998. Wheat production and grass production data, and soil C and N assessments will be accomplished in 1998. The native rangeland plots that were cultivated and wheat-fallow cropped since 1987 will be seeded to a mixture of native grasses in preparation for returning these sites to landowner. Sample analysis (1998) and data summarization will be accomplished and manuscripts evaluating soil aggregate distribution changes, soil C and N dynamics, and system C and N balance will be prepared.

[1] USDA-ARS, NPA, CGPRS, Akron, CO

UTILIZATION OF ANIMAL, MUNICIPAL, AND INDUSTRIAL WASTES ON SEMIARID RANGELANDS: SOIL AND VEGETATION RESPONSES

G.E. Schuman, J.D. Reeder, G.W. Frasier and R.H. Hart

PROBLEM: Rangelands are in demand as potential sites for utilization of municipal, industrial, and animal wastes. However, little information is available concerning the application of waste materials on rangelands where incorporation into the soil is not feasible. These wastes generally have the potential to supply N, P, and C to rangeland soils and improve both quantity and quality of the forage produced. However, the question of introducing heavy metals into the environment or food chain are a concern if these by-products contain such constituents.

APPROACH: This study is being conducted on a short-grass prairie (SE) and on a northern mixed-grass (MG) prairie. Treatments consisted of surface applications (23 t/ha) in May 1993, of (1) fresh feedlot cattle wastes (FM), (2) composted feedlot cattle wastes (CM), (3) dried sewage sludge (DS), (4) PH phosphogypsum (PH), (5) PH + N, and (6) control (C).

RESULTS: Peak vegetation production data were collected in 1997. Response of vegetation to the applied wastes differed considerably between the two field sites. The MG community is composed of more cool-season species than present on the SG site, which are more responsive to N and P. Total production was greater for all waste treatments compared to the control on the MG site; however, only the phosphogypsum + N treatment was greater at the SG site. Cool-season (C_3)species represented a major portion of the annual production on the MG while they only represented about 10-30% of the production on the SG prairie. Table 1 shows the production data for the MG site.

Component	Waste Treatment					
	CM	FM	C	PH	PH+N	DS
	kg/ha					
Ann. Forb	0	4	1	9	1	11
P. Forb	134	77	123	208	151	66
Cactus	-	-	-	-	-	1
Carex	46	9	42	69	96	38
C_3 grass	1207	741	450	401	1191	874
C_4 grass	286	410	312	204	290	272
Other	160	336	481	732	148	573
Total	1834	1577	1409	1623	1879	1687

FUTURE PLANS: The 1993-1997 plant production, plant quality, soil nutrient, soil and plant heavy metal, and plant community composition data are being summarized to determine if a second application of the by-products will be applied in 1998. Data summarization will be continued and manuscripts prepared.

CARBON UPTAKE ON THE SHORTGRASS PRAIRIE

J.A. Morgan, D.R. LeCain, G.E. Schuman, J.D. Reeder and R.H. Hart

Problem: As atmospheric greenhouse gasses continue to increase and recent reports suggest climatic change may be underway, there is a critical need to understand how environment and management affect carbon fluxes and storage in grasslands. This information is required to understand how best to manage our rangelands for sustained productivity while protecting this resource from degradation. Knowledge of the capability of grasslands to assimilate and store carbon is also needed for understanding how these systems interact with the global carbon cycle.

Approach: Closed-chamber measurements of CO_2 assimilation rates (A) of meter square areas of short-grass steppe (SGS, Nunn, CO) and northern mixed-grass prairie (NMP, Cheyenne, WY) plus soil water, temperature, and vegetation cover have been measured for three years on heavily- and lightly-grazed pastures as well as on long-term exclosures. Bowen ratio/energy balance measurements of CO_2 and H_2O have also been made on an exclosed (CO) and lightly-grazed pasture (WY) to determine seasonal and diurnal flux rates.

Findings: Three seasons of measurement (1995-1997) revealed that grazing enhances early spring A in NMP due to earlier spring green-up compared to exclosures. As the growing season progressed, green leaf area and A increased in all pastures, but more so in the ungrazed exclosures, resulting in occasional higher A compared to grazed pastures. Seasonal differences in grazed and exclosed pastures in the SGS were not as simply related to green leaf area, but reflected differences in photosynthetic functional groups as well. A cool, wet spring in 1995 resulted in higher early-season A in the cool-season, C_3-species dominated exclosures, whereas the warm, dry spring of 1996/97 resulted in higher A in the warm-season, C_4-species dominated grazed pastures. Differences in A due to grazing in the SGS diminished by July. Grazing influenced A primarily through changes in species composition on the SGS, while grazing caused earlier spring green-up and improved A on the NMP. Bowen ratio measurements of A began in 1996, and a limited data set is currently being analyzed. Initial analyses show good correspondence between gas fluxes and light and precipitation events.

Future Plans: This is the final year for the chamber CER measurements. A manuscript will be written this winter and submitted in the spring to a journal. More effort will be spent in the following years on the Bowen Ratio measurements. We will take some limited paired comparisons between Bowen Ratio and chamber measurements to compare methodologies, and add cellular phone connections to the WY and CO stations to allow more frequent monitoring.

RESPONSES OF PRAIRIE GRASSES TO DEFOLIATION, NITROGEN & CO_2 ENRICHMENT

J.A. Morgan, R.H. Skinner[1], G.L. Hutchinson[2], J.D. Hanson[1], J.D. Reeder and G.E. Schuman

Problem: Most research into plant response to increasing atmospheric CO_2 concentrations has focused on cultivated, mostly C_3 species. Few studies have considered native ecosystems in which C_4 grasses are important components, and fewer yet in the context of how elevated CO_2 might interact with management practices. Knowledge of how elevated CO_2 concentrations may interact with plant physiology/ecology under different management practices will be necessary for formulating intelligent management alternatives as global change progresses.

Approach: In order to investigate how defoliation (grazing) interacts with plant response to CO_2 enrichment, two growth chamber studies were instigated. The first study was completed this past year, and evaluated how growth at two levels of CO_2 (350 and 700 $\mu L\ L^{-1}$) and two levels of N fertility affected re-growth and re-mobilization of C and N reserves in twenty days following defoliation in *Pascopyrum smithii* (C_3), *Bouteloua gracilis* (C_4), and *Medicago sativa* (C_3). A second study was begun this spring, and evaluates growth, resources partitioning, as well as system C and N cycling in 30-cm depth, 25 cm-diameter cores of soil/sod from the northern mixed prairie to one seasons growth at 350 and 700 $\mu L\ L^{-1}$ CO_2, two levels of N (un-fertilized and N fertilized), and two defoliation treatments (none and defoliation once in the early summer).

Findings: In the first experiment, re-growth of all three species was enhanced at the higher level of N fertility. Elevated CO_2 also enhanced regrowth of the two C_3 species, but inhibited re-growth in the C_4, *B. gracilis*. All three species were unable to convert total non-structural carbohydrates (TNC) into structural materials fast enough to keep up with the increased carbon supply at elevated CO_2, so TNC accumulated in above- and below-ground tissues. Carbohydrate concentrations were not simply related to re-growth, nor were there consistent correlations between carbohydrate or nitrogen remobilization and re-growth in the initial four days after defoliation. Data are still being collected in the second study, but visual observation indicates a strong growth enhancement in the mixed-grass prairie at the higher levels of N fertility and CO_2.

Future Plans: Two manuscripts are in preparation describing responses of the three species, one focusing on growth responses, the other on re-mobilization of C and N compounds. A third modeling manuscript will follow, examining how partitioning and re-growth of these species respond to the environment. The second growth chamber study is slated to run next summer (1998) to obtain two more complete replications of the experiment. Data analysis and interpretations will follow.

[1]Great Plains Systems Research, Ft. Collins, CO
[2]Soil-Plant-Nutrient Research Unit, Ft. Collins, CO.

GLOBAL CHANGE IN THE SHORTGRASS STEPPE: EXPERIMENTATION & MODELING

J.A. Morgan, H.W. Hunt[1], D.R. LeCain, J.J. Read[2] and D.X. Chen[1]

Problem: Plant species with the C_3 photosynthetic pathway are perceived to be most responsive to increased atmospheric CO_2 concentrations, so research has focused primarily on them and has neglected plants with the C_4 photosynthetic pathway. However, information from our group and a few others suggest that, under some conditions, C_4 species may exhibit substantial growth responses to rising CO_2 concentrations. The shortgrass steppe of eastern Colorado contains a mixture of both C_3 and C_4 grasses. Information on the physiological responses of shortgrass steppe photosynthetic functional groups and possible effects on their adaptability and competitiveness are needed to predict how elevated CO_2 will affect the ecology of this region.

Approach: Growth chamber and associated modeling experiments were completed that evaluated basic physiological responses of C_3 and C_4 grasses to elevated CO_2 and water. In the first study, photosynthesis, carbohydrate metabolism, water relations, plant growth and partitioning, and nutrient uptake were evaluated in *Pascopyrum smithii* (C_3) and *Bouteloua gracilis* (C_4) grown at two CO_2 levels and two water levels. In a second investigation, photosynthetic responses to CO_2 were investigated in six grass species from two of the three C_4 decarboxylation sub-types. We hypothesized that NAD-ME C_4 species, which are believed to be the least efficient C_4 sub-type, would respond more to CO_2 compared to the more efficient NADP-ME sub-type.

Findings: In the first experiment, leaf CO_2 assimilation, transpiration use efficiency, plant growth, and whole-plant water use efficiency of both species were greater at elevated CO_2, although responses were more pronounced for *P. smithii*. Declining soil water content with time was associated with an increased sequestering of total non-structural carbohydrates, storage carbohydrates and biomass in belowground organs of *P. smithii*, but not *B. gracilis*. Modeling exercises predicted growth and biomass partitioning responses of *P. smithii* and *B. gracilis* accurately based on their photosynthetic pathway and the balanced growth concept. In a second experiment, we found no evidence to support the notion that differences in growth or photosynthetic responses among six C_4 grass species relates to their particular decarboxylation sub-type. More importantly, we found no evidence that photosynthesis in any of the C_4 grasses was CO_2-saturated at present CO_2 concentrations under the conditions of the study.

Future Plans: Modeling exercises are proceeding with the photosynthesis and water relations data to determine how elevated CO_2 affects photosynthesis through its combined effects on water relations and plant metabolism. Further experiments are being considered to further evaluate C_4 photosynthetic and water relations responses to elevated CO_2 and temperature.

[1]Natural Resource Ecology Lab, Colorado State University, Ft. Collins, CO
[2]U.S. Salinity Lab, 450 Big Springs Rd., Riverside, CA

CO_2 ENRICHMENT ON THE SHORTGRASS STEPPE: ECOPHYSIOLOGY

J.A. Morgan, A.R. Mosier[1], D.R. LeCain, D.G. Milchunas[2], W.J. Parton[3] and D. Ojima[3]

Problem: Since atmospheric CO_2 concentrations are increasing, it is incumbent upon those of us working in rangelands to understand how such increases will affect the ecology of American's extensive grasslands. Previous growth chamber experiments have indicated that growth and physiology of both C_3 and C_4 native shortgrass steppe grasses respond significantly to elevated CO_2. This study was initiated to conduct such an evaluation under more realistic field conditions, and also to determine how elevated CO_2 trace gas fluxes (see Mosier report in SPN Unit).

Approach: In early spring 1997, six hexagonal open-top chambers measuring 4.6 m in diameter by 3.7 m in height were installed on native shortgrass steppe in northeastern Colorado, USA. Carbon dioxide was injected into three elevated chambers to raise concentrations to 700 $\mu L\ L^{-1}$, approximately twice the concentrations measured in the three ambient chambers. Three additional non-chambered plots were established to evaluate chamber effects. Chambers remained in place for the entire growing season, and were removed after fall senescence. Soil and plant attributes were determined periodically to investigate the effects of elevated CO_2 on the system's ecology.

Findings: The grassland community at the experimental site is comprised of over 25 species, but dominated by three grasses, *Bouteloua gracilis* (C_4, 42% of aboveground biomass), *Pascopyrum smithii* (C_3, 21%) and *Stipa comata* (C_3, 26%). Aboveground seasonal production in 1997 under elevated CO_2 (278 g m^2) was 30% greater compared to that in the ambient chambers (214 g m^2), while production in ambient chambers exceeded that in control plots (155 g m^2) by 38%. Significant growth enhancements from elevated CO_2 were realized for both C_3 and C_4 grasses, and were related to higher leaf water potentials and soil water contents as well as higher photosynthesis rates and accumulation of leaf non-structural carbohydrates. Gas exchange data indicated consistent and significant downward photosynthetic acclimation in the C_3 grass throughout the growing season under CO_2 enrichment.

Future Plans: NSF funding (Milchunas et al.) was recently obtained to investigate aspects of soil microbiology related to C and N cycling, and to extend the study for a total of five years. We will continue the plant measurements made last year, and add photosynthetic light response curves, leaf anatomical measurements and plant metabolites to more fully investigate plant acclimation to CO_2 enrichment and to obtain data needed for ecophysiological models of plant response.

[1] Soil-Plant-Nutrient Research Unit, Fort Collins, CO
[2]Dept. of Rangeland Ecosystem Science
[3]Natural Resource Ecology Lab, Colorado State University, Fort Collins, CO.

HYDROLOGIC CHARACTERISTICS OF A MONTANE RIPARIAN ZONE

G.W. Frasier, M.J. Trlica[1], W. Leininger[1], M. Flenniken[1], R. McEldowney[1] and M. Wheeler[1]

PROBLEM: Riparian ecosystems are a key component, in many places, of the rangeland resource with respect to livestock and wildlife foraging areas. These areas are also critical elements in removing sediments from overland water flow. There is a concern that heavy utilization of these areas by livestock and wildlife can affect their ability to effectively trap sediment and reduce non-point source pollution to streams.

APPROACH: Single ring infiltrometers and rotating boom rainfall simulators were used to evaluate the effects of cattle grazing and trampling on infiltration, runoff, and sediment movement in a montane riparian grass community .

RESULTS: Preliminary evaluation of ring infiltrometer data indicate a reduced rate of water infiltration as a result of increased soil bulk density below the soil surface following intensive cattle trampling. The areas reverted to pretreatment bulk density values and infiltration rates after one winter of non-use. Observations during rainfall simulations indicate that cattle trampling and grazing reduce the time of runoff concentration by changing micro-topographic flow paths to a more direct route. Even with extensive trampling by livestock, the areas were effective in filtering and trapping sediment from overland flow water.

INTERPRETATION: These results indicate that runoff and infiltration processes in the riparian zone can initially be affected by cattle grazing and to a lesser extent cattle trampling but the effects are reversed by freezing and thawing during the winter periods. These preliminary results indicate that intermittent cattle trampling and grazing does not create any lasting detrimental effects with respect to riparian areas serving as a sink for water borne sediments. These results are important in developing management criteria for riparian zones.

FUTURE PLANS: Analysis of the data will be completed and technical reports of the results will be prepared for publication.

[1] Department of Rangeland Ecosystem Management, Colorado State Univ, Ft. Collins, CO

EROSIONAL SOIL LOSS AND ITS EFFECTS ON RANGELAND HEALTH

G.W. Frasier, W. Leininger[1], M.J. Trlica[1], R.D. Child[1], G.E. Schuman and J. Smith[2]

PROBLEM: Many of the current rangeland assessment programs utilize vegetation components such as composition and productivity as indicators of rangeland condition and health. In reality, plants are only indicators of interactions among climate, soil, water, nutrients and past history of use. Loss of soil through wind and water erosive actions removes valuable nutrients and organic matter that supports plant cover and production. As soil and plant nutrients are lost, then the plant component of the ecosystem responds to this change. However, little is presently known about the direct effect of soil loss on vegetation cover, composition and productivity and how these losses ultimately affect rangeland health.

APPROACH: Studies are being initiated on a shortgrass prairie site at the Central Plains Experimental Range (CPER) to evaluate the effect of soil losses (0, 5 and 10 tons/acre) on hydrologic, vegetative and soil changes. Plots will be established where the desired level of soil removal will be eroded using a vacuuming technique. Superimposed on the soil loss levels will be various initial range conditions and plant densities. A complete soil and plant quality assessment will be done prior to and at periodic intervals following the erosion event to determine changes that might occur through time, rangeland condition and trend (i.e. health), and rates of recovery. Vegetation measurements will include estimates of cover by individual species, productivity as measured by CO^2 exchange for dominant species, and above ground and below ground biomass. Included in the measurements are hydrologic parameters (runoff, infiltration sediment yield, surface roughness, flow paths) and soil parameters (bulk density, litter cover, rock cover, bare ground, organic matter, C:N ratio).

RESULTS: Preliminary studies have shown that the vacuuming technique is feasible for removing the desired amount of soil from the plots.

INTERPRETATION: These studies are expected to define whether soil losses actually affect ecosystem functions (i.e. productivity, nutrient cycles) or health of rangelands or what level of soil loss is critical to these processes or evaluations.

FUTURE PLANS: Full scale field studies will be initiated at CPER in the spring of 1998. A second site in a sagebrush steppe ecosystem will be selected and included in the studies as techniques are developed and verified.

[1] Department of Rangeland Ecosystem Management, Colorado State Univ, Ft. Collins, CO
[2] Department of Civil Engineering, University of Wyoming, Laramie, WY

ICE IN WINTERFAT SEEDS

D.T. Booth, Y. Bai [1] and J.T. Romo[2]

PROBLEM: When wet lettuce seeds freeze they die. Yet, native-plant seeds of the Northern Great Plains are regularly exposed to snow melt followed by -30°C or colder conditions. We wished to know if this killed seeds of native winterfat, and if not, why? The answers will help restore winterfat to overgrazed ranges and may help us design crop seeds that are more tolerant to freezing stress.

APPROACH: We measured the effects of freezing on wet (fully hydrated) winterfat (Eurotia lanata (Pursh) Moq.) seeds harvested from the Northern Plains at two USA and one Canadian location. Winterfat diaspores (seed containing dispersal units) were hydrated at 0, 5, 10, and 20°C in darkness to full hydration. Full hydration was defined as 8 hours before germination at the hydration temperature. This required about 24 hours incubation time for diaspores at 20°C, and 120 or more hours incubation time for diaspores at 0°C. The diaspores were then placed in an incubator at 0°C for 1 hour before being moved into a freezer programmed to cool at 2.5°C per hour from 0 to -30°C over a 12 hour period. Diaspore and air temperatures were recorded with a Campbell Scientific CR7 data logger. When an ice crystal forms it gives off heat as an exotherm. Exotherms were detected by comparing the difference in diaspore and air temperatures at 1-minute intervals through the cooling period. A second sample of diaspores was cooled to -50°C at the same rate and monitored in the same way.

RESULTS: Fully hydrated winterfat diaspores had two ice forming events which were evident by a high temperature exotherm (HTE) and a low temperature exotherm (LTE). The temperatures at which HTEs and LTEs occurred were similar among collections, but differed by the temperature at which the seeds were hydrated. Seeds hydrated at 0 or 5°C had HTEs at warmer temperatures than those imbibed at 10 or 20°C, averaging -4.1 and -4.2; and, -4.9 and -5.0 C for the respective imbibition temperatures. The average temperature for all LTEs was -17.6°C. The range was -3.7 to -26.8°C with 12% of all LTEs occurring at, or warmer than, -10°C. Seeds imbibed at 0°C had LTEs at warmer temperatures than seeds imbibed at 5, 10 or 20°C. Up to 41% of diaspores imbibed at 0°C had the second exotherm (LTE) at, or warmer than, -10°C. No diaspores were observed to have more than two exotherms, including those cooled to -50°C.

FUTURE PLANS: We will continue to seek to understand how native plant seeds and seedlings respond to environmental stresses of the Northern and Central Great Plains.

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[2]Department of Crop Science and Plant Ecology, Univ. of Saskatchewan, Saskatoon, Saskatchewan, Canada.

WINTERFAT DEVELOPMENT AND SEEDLING SURVIVAL AFTER FREEZING

Y. Bai[1], D.T. Booth and J.T. Romo[2]

PROBLEM: Winterfat seedlings have high first-year mortality. This hinders mined land reclamation and rangeland restoration. Since some of this mortality might result from freezing stress, therefore, we wished to determine winterfat's post-germination freezing tolerance. We hypothesized that decreasing freezing tolerance occurred with increasing post-germination development.

APPROACH: Our objectives were to determine: 1) temperatures at which exotherms occur (an exotherm is the heat given off when ice forms), 2) the relationship between exotherm occurrence and the survival and growth of winterfat germinants after cooling, and 3) how freezing tolerance is related to developmental stage. Diaspores (seed containing dispersal units) of winterfat (*Eurotia lanata* (Pursh) Moq.) collected from 2 locations in the USA and 1 in Canada were imbibed at 10°C and grown for 2, 3, 6, and 14 days, then subjected to cooling temperatures as low as -30°C. Diaspore and air temperatures were recorded with a Campbell Scientific CR7 data logger. When an ice crystal forms it gives off heat as an exotherm. Exotherms were detected by comparing the difference in diaspore and air temperatures at 1-minute intervals through the cooling period. The temperatures at which exotherms occurred were recorded, and the subsequent growth and mortality of germinants were determined.

RESULTS: Only 1 exotherm was observed for each germinant cooled to -30°C. The temperature at which that exotherm occurred was usually equal to or colder than -10°C. Changes in the freezing tolerance of germinants from seed to seedling was a gradual process as indicated by increases in exothermic temperatures with increasing development. Increasing development also increased freezing related germinant mortality. Whether the exotherm indicated a lethal event depended on the developmental stage of the germinant. The temperature at which an exotherm occurred increased from an average -13.3 at 2 days of incubation to -7.6°C for 14-day-old germinants. Germinants at 3 days of incubation or older were killed when exposed to -30°C. Otherwise mortality of 2, 3, 4, and 6 day-old germinants was less than 16%. Germinant survival was also affected by cooling below the exotherm temperature.

FUTURE PLANS: We postulate that germinants which develop under a diurnal cycle that includes regular exposure to freezing stress will either not progress in their development, or will be more tolerant to freezing stress than germinants with a similar degree of development that have not been exposed to regular freezing events. We plan to test this hypothesis.

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THE EFFECT OF WATER STRESS ON THE GERMINATION OF BIG SAGEBRUSH

Y. Bai[1], S.P. Hardegree[2], D.T. Booth and E.E. Roos[3]

PROBLEM: Sagebrush is commonly recommended for ecological restoration in shrublands of the arid western United States. Although sagebrush is common throughout the west, the seedbed ecology, including the amount of moisture needed for germination, is not well understood.

APPROACH: Seed for commerce are usually harvested from native stands and cleaned with a debearder (a machine originally developed to remove awns from seeds) before being sold. Processed sagebrush seeds have a significant proportion of seeds with the pericarp removed. To determine the effect of water stress on germination, and to determine if pericarp removal had any influence on this relationship we tested sagebrush seed germination at seven water potentials from 0 to -1.5 MPa for intact seeds and for seeds with the pericarp removed. Two different seed collections were used in the study. Seeds were humidified to the test moisture level using a membrane-bottom germination cup which was in contact with an osmotic solution of PEG 8000. The seeds rested on the membrane surface which maintained a matric potential equal to the osmotic potential of the PEG in the solution reservoir. Twenty seeds were placed on the membrane surface for each treatment. Seeds were imbibed at 5°C in darkness for four days, then incubated at 20 C under 12 hours light for an additional 14 days. Germination was checked daily and seeds with radicles equal to, or greater than 5 mm were considered germinated.

RESULTS: Germination without water stress ranged from 59 to 69%. Germination decreased as the water potential became more negative. At -0.25 MPa about 50% of seeds germinated. Germination decreased to less than 23% below -0.75 MPa. At -1.26 MPa and below, the germination was less than 1 %. For one of the seed collections the presence of the pericarp slightly, but significantly, reduced seed water up take. Percent germination was reduced for that collection at -0.50 MPa from 38% for seeds without pericarp to 31% for seeds with pericarp, and at -0.70 MPa from 22 to 13%. Although some advantage was found for removing the seed pericarp, we conclude that the pericarp helps protect some seeds from germination during suboptimal conditions. We recommend sowing a mixture of seeds with and without pericarp. This will increase the probability for germination of a significant fraction (20 to 30%) of the seedlot, but also leaves the majority of seeds intact. The mixture is the natural result of conservative processing by conventional commercial methods.

FUTURE PLANS: We have no plans to continue this study.

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GRASS: GRAZING RATES AND STRATEGIES STUDY

R.H. Hart, G. E. Schuman, J.W. Waggoner, Jr.[1] and M.A. Smith[1]

PROBLEM: Claims for the benefits of short-duration or time-controlled rotation grazing systems have received a great deal of publicity and some official recognition by NRCS and other agencies. A study was begun in 1982 to evaluate the responses of cattle, vegetation, soils, and hydrology to three grazing strategies at three stocking rates.

APPROACH: Crossbred and Hereford steers initially weighing 228 kg grazed native range 30 May-24 Sep 1997. Strategies included continuous or season-long grazing © and time-controlled rotation grazing in 8 (S8) and 24 (S24) paddocks. Stocking rates in 1997 were 20.5 (light), 48.8 (moderate) and 65.0 (heavy) steer-days ha^{-1}. Steers were weighed every 28 days. Peak standing crop (PSC) and residual herbage after grazing were estimated inside and outside 4 exclosures per pasture 29 and 30 Sep.

FINDINGS: Peak standing crop was 2036 kg ha^{-1} on light stocking, 1510 on moderate, and 1222 on heavy, with no differences among strategies; this is the first year since the study began in 1982 in which production was higher on light than on moderate or heavy stocking. Average daily gains were CL, 0.98; CM, 0.93; CH, 0.96; S8M, 0.79; S8H, 0.85; and S24H, 0.64 kg. Gains under time-controlled rotation grazing were significantly less than gains under season-long grazing, and gains on S24H were less than gains on S8H.

FUTURE PLANS: A manuscript covering the first 13 years of this study was published in November 1997 in the *Journal of Range Management*. This study will be continued at least through 2000.

[1] Dept. of Renewable Resources, University of Wyoming

LONG-TERM GRAZING INTENSITY STUDY, CENTRAL PLAINS EXPERIMENTAL RANGE

R.H. Hart and M. Ashby

PROBLEM: Studies of the impact of grazing intensity on steer gains and range vegetation seldom last more than a few years. Data is needed on effects over several decades.

APPROACH: In 1939, a replicated study of 3 grazing intensities was begun at the Central Plains Experimental Range. Over the years replications were dropped until by 1960 a single pasture of each of 3 intensities remained. In 1997, yearling heifers grazed the study 13 May-30 Oct at light, moderate or heavy stocking rates of 15, 20 or 25 heifers per 129.6 ha (320 acres) or 19.7, 26.2 or 32.8 heifer-days ha^{-1}. Heifers were weighed every 4 weeks. Peak standing crop was estimated from exclosures distributed over the entire area of each pasture.

FINDINGS: Average daily gains of heifers were light, 0.69; moderate, 0.65; and heavy, 0.58 kg. Peak standing crops were light, 1266; moderate, 1158; and heavy, 913 kg ha^{-1}. This manuscript was accepted for publication: Hart, R. H., and M. M. Ashby. Grazing intensities, vegetation, and heifer gains: 55 years on shortgrass. J. Range Manage. 51:(in press, accepted 2 Nov 1997). 1998.

FUTURE PLANS: This study will be continued indefinitely.

GRASS CPER: GRAZING STRATEGIES ON SHORTGRASS AT CPER

R.H. Hart

PROBLEM: Large-pasture studies of the impact of grazing strategies on shortgrass prairie are needed.

APPROACH: Time-controlled rotation grazing was implemented on a 7-paddock layout, each paddock containing 65 ha (160 acres). One paddock was sub-divided into 3 equal sized sub-paddocks; these mimic a portion of a 21-paddock layout. An undivided 259-ha (640 acres) pasture was grazed season-long. Three-pasture rotationally deferred grazing was implemented on three 152-ha (373 acre) pastures, with grazing on one pasture deferred until July. Stocking rate was 22.9 steer-days ha^{-1}, from 12 May-8 Oct 1997. Steers were weighed on and off pasture. Forage production and botanical composition were estimated at approximately peak standing crop.

FINDINGS: Average daily gains of steers were season-long, 1.03; time-controlled rotation, 1.06; and rotationally deferred grazing, 0.87 kg. Differences in gains may have reflected differences in production and botanical composition, particularly of grasses and pricklypear cactus.

	Season-long	7-paddock	21-paddock	Rotation deferred
	kg/ha			
Western wheatgrass	142	70	33	47
Blue grama	685	721	503	694
Buffalograss	1	0	0	123
Inland saltgrass	137	22	0	0
Bottlebrush squirreltail	16	39	223	18
Alkali sacaton	485	49	0	0
Needleandthread	25	265	358	17
Total graminoids	1537	1232	1140	937
Forbs minus pricklypear	127	199	114	140
Total grasses & forbs, minus pricklypear	1664	1431	1254	1077
Pricklypear	359	539	1258	490

FUTURE PLANS: This study will be continued for at least 12 years. Production will be estimated annually, but botanical composition will not be estimated again until after several more years of grazing. Soils and vegetation at the beginning of the study differed so much among pastures that vegetation changes will be analyzed by analysis of covariance, using average botanical composition of the first 3 years as a covariate.

GRIPES: GRAZING RANGE AND IMPROVED PASTURE EXPERIMENT ON SHORTGRASS

R.H. Hart

PROBLEM: Costs of cattle production could be reduced if the grazing season could be extended by grazing complementary pastures in spring and/or fall, before and after the grazing season on shortgrass rangeland.

APPROACH: Two pastures of 16 ha each, containing dense uniform stands of fourwing saltbush, were stocked 31 Oct 1996-9 Jan 1997 at 21.9 (light) and 35.0 (moderate) heifer-days ha^{-1} and 1 Apr-13 May 1997 at 13.8 and 22.0 heifer-days ha^{-1}. 'Hycrest' wheatgrass and 'Bozoisky' wildrye were stocked under S&FL at 21.9 heifer-days ha^{-1} in fall and 31.2 heifer-days ha^{-1} in spring, or at 29.2 and 41.7 heifer-days ha^{-1} under S&FM. Bozoisky was stocked at 43.8 (FL) and 58.3 (FM) days ha^{-1} in fall only. Hycrest was stocked at 62.5 (SL) or 83.3 (SM) days ha^{-1} in spring only. Fall grazing was 31 Oct-5 Dec 1996 and spring grazing was 14 Apr-3 Jun 1997. After spring grazing, heifers were moved onto native rangeland. Plant community compositions of these pastures, and of rangeland pastures grazed beginning in May, will be estimated as baseline data for a comparison of the effect of delayed spring grazing.

FINDINGS: Under light and moderate stocking on saltbush, fall-winter 1996-97, ADG was 0.46 and 0.33 kg, respectively; in spring 1997, ADG was 0.17 and -0.29 kg. On 5 June 1997, mean standing crops of Hycrest and Bozoisky were 895 and 1014 kg ha^{-1}, respectively. Gains on wildrye and wheatgrass were:

		----31 Oct-5 Dec 96----			----1 Apr-3 May 97----			Total
	Season	d/ha	ADG, kg	kg/ha	d/ha	ADG, kg	kg/ha	kg/ha
Bozoisky	S & F	21.9	0.60	13.2	31.2	0.77	24.2	37.4
wildrye		29.2	0.56	16.3	41.7	.74	30.8	47.1
	Fall	43.8	0.52	22.9	--	--	--	22.9
		58.3	0.45	26.3	--	--	--	26.3
Hycrest	Spring	--	--	--	62.5	0.88	55.1	55.1
wheatgrass		--	--	--	83.3	0.71	59.0	59.0
	S & F	21.9	0.20	4.2	31.2	0.89	27.8	32.0
		29.2	0.56	16.3	41.7	1.02	42.4	58.7

Two articles were published in the Proceedings of the XVIII International Grassland Congress; see publications list.

FUTURE PLANS: This study will continue for 5 more years.

SUSTAINABLE RANGELAND-BASED BEEF CATTLE PRODUCTION SYSTEMS (SARE GRANT)

R.H. Hart, J.W. Waggoner, Jr.[1] and M.A. Smith[1]

PROBLEM: Changing calving and weaning dates to match more closely the nutrient requirements of a cow-calf herd to the availability of green forage has been suggested as a way of reducing production costs and increasing sustainability of a cow-calf operation.

APPROACH: In 1997, fifty-six Hereford cows calved 21 Feb-29 Mar (March calving) or 8-29 May (May calving). Cow-calf pairs were stocked on native range 2 June-10 November at 5.14 or 6.29 ha per pair. Calves were weaned at mean ages of 154 or 178 days old.

FINDINGS:

Calved	Stocking rate	Weaning age, days	Cows: Weight 10 Nov	Cows: Year ADG	Calves: Weight Weaning	Calves: Weight 12 Nov	Calves: Year ADG
			lb				
March	Moderate	160	1275	1.18	476	514	1.45
		183	1294	0.92	503	525	1.69
	Heavy	155	1315	0.63	451	495	1.41
		178	1262	0.63	491	507	1.58
May	Moderate	152	1070	0.06	439	431	1.83
		175	1101	0.12	470	470	2.14
	Heavy	150	1079	0.13	433	413	1.82
		176	1129	0.12	423	423	1.79

Economic analysis will determine whether reduced weaning weights from heavy stocking and May calving will be compensated for by greater weaned weight/ha and higher prices for lighter calves later in the season, respectively. May-calving cows will also require more winter feed to restore them to condition for calving and breeding the following year.

FUTURE PLANS: This study will continue for 2 more years. It may be re-designed and continued longer after analysis of the first 3 years of data.

[1] Dept. of Renewable Resources, University of Wyoming

DETERMINATION OF GRASS GROWTH AND QUALITY BY MONTH

D.A. Gasseling [1], R.H. Mandel [1] and C.B. Ring [1]

PROBLEM: The Grazing Lands Application (GLA) computer model uses growth curves of plants by months to allocate available forage. Many grasses do not have the per cent growth available by month.

APPROACH: The Natural Resources Conservation Service conducted field clippings on six grass species on plots during summer of 1997. The plots are located on the High Plains Grasslands Research Station (HPGRS). Clippings were completed the first five days of June, July, August, and September. The grass was clipped at an approximate height of 3 inches. The grass samples were oven dried and weighed. The HPGRS completed tests for protein (% Nitrogen), phosphorous, calcium, magnesium, and potassium on the samples. The results list the information for 4 of the 6 grasses. If you would like the information for Siberian wheatgrass, Newhy or Hycrest, contact the NRCS GrazingLands Resource Technical Team.

RESULTS:

Species	Month	ADW[2]	%G[2]	N	P[2]	Ca[2]	Mg[2]	K[2]
Rosana WWG	June	258.3	46.4	2.04	2230.5	1752.0	254.5	13896.0
	July	2066.7	53.6	1.22	1563.3	1190.7	132.9	8001.3
	August	958.3	0.0	0.83	1048.4	1908.0	311.6	6058.7
**	September	1308.3	16.9	1.10	1293.7	2405.3	346.8	6026.7
Manska PWG	June	1550.4	72.6	1.62	2052.8	1941.3	369.2	9718.7
	July	2135.5	27.4	1.06	1768.5	1341.3	216.4	8237.3
	August	2120.9	0.0	0.64	1265.6	1480.0	338.7	4348.0
**	September	2450.0	15.4	1.18	1519.0	2342.7	459.2	6152.0
Bozoisky RWR	June	987.3	72.2	2.43	2870.1	2149.3	524.5	20168
	July	1367.6	27.8	1.51	2132.9	2505.3	597.5	25017.3
	August	965.4	0.0	1.0	1189.2	2076.0	666.1	4669.3
**	September	1594.3	46.0	1.6	2407.7	2837.3	937.6	11005.3

** August regrowth due to 5.14 inches of moisture.

[2] ADW - Air Dry Weight, %G - % growth for month, P, Ca, Mg, K - reported in parts per million (ppm).

FUTURE PLANS: To continue the clippings for a full season to gather the growth data by month for verification of growth curve information for the Grazing Lands Application computer model.

[1] Natural Resources Conservation Service, Cheyenne Grazinglands Resource Technical Team, Cheyenne, WY

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SOIL-PLANT-NUTRIENT RESEARCH

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MISSION STATEMENT

To develop and evaluate new knowledge required to efficiently manage soil, fertilizer and plant nutrients (emphasis on nitrogen) to achieve optimum crop yields, maximize farm profitability, maintain environmental quality and sustain long-term productivity.

TECHNOLOGICAL TRANSFER

Dr. J.A. Delgado

Dr. Jorge Delgado, Dr. Marvin Schaffer, and Ms. Mary Brodahl using data collected from the San Luis Valley studies, have incorporated modifications into a new version of the USDA-ARS Nitrogen Leaching Economic Analysis Package (NLEAP). A new version NLEAP 1.2 was developed to improve predicted simulations of residual soil NO_3^--N and evaluation of effects of N management practices in water quality.

Dr. Delgado presented a seminar, in the 1998 SWCS annual conference in Toronto Canada, about potential use of a new Version of NLEAP as a technology transfer tool to assess the effects of cropping sequence on residual soil NO_3^--N and N use efficiency.

Dr. Delgado met with San Luis Valley NRCS Area Office personnel to discuss effects of cropping management practices on soil quality and its relationship to water quality in the San Luis Valley. This transfer of information contributed to increase the knowledge about the sustainability of these systems.

Dr. Delgado, Dr. Sadao Shoji, Professor Emeritus of Tohuku University, Japan and Ms. Yulnafatmawita Lamsuddin, Agricultural College, Andalas University, Padang Indonesia visited with San Luis Valley farmers and with NRCS personnel about best management practices and water quality.

Dr. R.F. Follett

Dr. Follett served as a "Technical Expert" for the International Atomic Energy Administration (IAEA), Vienna, Austria. His mission was to Temuco, Chile (June 7-15, 1997) to instruct and assist scientists in their design of winter-wheat field experiments and use of ^{15}N isotope in their research to improve fertilizer N-use efficiency in the cropping systems, climate, and soils in Chile. Dr. Follett also gave four seminars covering topics including, (a) Use of ^{15}N fertilizer in field experiments, (b) Nitrate leaching and groundwater quality, (c) Global climate change, and (d) Chlorophyll meter use to predict N fertilizer needs of winter wheat. The Chilean scientist and project leader, Dr. Juan Luis Rouanet, visited Fort Collins in September (15-19, 1997) as a follow up of this technical transfer effort.

February, 1997 -- Invited by the American Society of Agronomy to serve on a Tri-society committee to respond to U.S. Senate questions concerning Agricultural Research. In many ways, responding to these questions provides technology transfer to the staff members with the Senate concerning how agricultural research is transferred from the work of the scientist to the farm and other user communities in the United States.

May 27-29, 1997 -- Invited to an OSTP/USGCRP workshop to help evaluate potential "Climate Change Impacts on the Great Plains". This was the lead off workshop to others being held throughout the United States and helped establish how future workshops need to be organized to address this same questions for other regions. Results of the workshop were fed into a National

Conference held in Washington D.C. (November 12-13, 1997), which Dr. Follett also attended and had input for National Policy makers in OSTP.

November 9-11, 1997 -- Invited to serve as a representative of the Soil Science Society of America at their "CROPS conference" in St. Louis, MO; a science and industry conference concerning future issues facing U.S. Agriculture and the possible role of research in addressing those issues. A report of the workgroup proceedings is to be prepared for the use of the participants and for sharing with policy makers.

Dr. Follett continues to interact regularly with Mexican scientists located at Celaya, Mexico, as part of a project funded by USDA/FAS/ICD/RSED to advise and conduct an ^{15}N study for a nitrogen by tillage/residue management field-experiment.

Dr. Follett, in cooperation with Dr. Rattan Lal (OH State Univ.) and Dr. John Kimble (NRCS), organized a conference in Columbus, OH entitled, "Carbon Sequestration in Soil". The Conference was attended by about 140 participants from 20 countries. That conference resulted in the publication of three books that were printed in late 1997 and are currently being distributed and serving to transfer technology worldwide concerning Soil Carbon Sequestration and its relation to Global Climate Change.

Dr. A.D. Halvorson

Dr. Halvorson, Dr. Berdahl, Dr. Krupinsky, and Mr. Rittle represented USDA-ARS with a poster depicting the research activities of the Northern Great Plains Research Laboratory at "Market Place '97" held at the Bismarck, ND civic auditorium on January 8, 1997. Several thousand people attended. The ARS video "Science In Your Shopping Cart" was shown to attendees at the Market Place with excellent comments. Several hundred copies of the ARS magazine "Science In Your Shopping Cart" were distributed.

Dr. Halvorson presented talks entitled "Rotations Will Add To Your Bottom Line" that addressed sunflower production in annual cropping systems at public informational meetings held for farmers at Hettinger, ND (Feb. 11, 1997), Gettysburg, SD (Feb. 12, 1997), and Minot, ND (Feb. 25, 1997). The meetings were sponsored by the National Sunflower Association.

Dr. Halvorson organized an informational meeting for farmers, agribusiness, and public to report the research results for 1996 from the cooperative Area IV SCD-ARS Research Farm. The meeting was held at the Seven Seas motel in Mandan, ND on February 19th, 1997. He reported his work on cropping systems and row spacing effects on corn and sunflower production.

Dr. Halvorson presented an invited talk on "Successful Dryland Cropping and Tillage Systems in the Great Plains" at the Annual Review of the Columbia Plateau PM_{10} Project for Wind Erosion and Air Quality meeting held in Richland, WA on Feb. 20-21, 1997. The meeting was sponsored by USDA-ARS, USDA-NRCS, EPA, Coop. Ext. Service, University of Idaho, and Washington State University.

Dr. Halvorson presented current research information on cropping systems, tillage, and N management at farmer meetings sponsored by DeKalb Seeds and DowElanco at Mott and New England, ND (Feb. 26, 1997) and at Mobridge, SD (Feb. 27, 1997).

Dr. Halvorson presented an invited paper entitled "Improving Sustainability of Dryland Cropping Systems" at a Sustainable Ag conference held in Aberdeen, SD, March 5-6, 1997 sponsored by the Sustainable Ag Committees and Cooperative Extension Service in North and South Dakota.

Dr. Halvorson presented an invited talk on "Cropping Systems and Fertilizer Management for Optimum Crop Yields" at a farmer meeting in Bowman, ND (March 19, 1997) sponsored by Bowman Grain Company.

Dr. Halvorson spoke on USDA-ARS Northern Great Plains Research Lab research activities/program to Mandan Lions Club (March 3rd, 1997), Bismarck Wednesday Morning Breakfast Club (May 7th), Bismarck-Mandan Chamber of Commerce (May 8th, 1997) and Mandan Kiwanis Club (May 22nd).

Dr. Halvorson, at the invitation of KFYR Radio in Bismarck, ND participated in a two hour "Call-In Show" that addressed USDA-ARS research at the Northern Great Plains Research Laboratory on June 10, 1997.

Dr. Halvorson conducted a field tour of USDA-ARS cropping systems research for ND Grain Growers Association and congressional aides on June 12, 1997.

Dr. Halvorson participated in a CSREES review of the NDSU Soils Department on June 18, 1997 at the request of the Soils Department staff.

Dr. Halvorson organized a Field Day for the public to view current research projects being conducted by USDA-ARS at Mandan, which was held on June 19, 1997.

Dr. Halvorson conducted a tour of the USDA-ARS and NDSU Ext. Service site-specific farming project for the staff of USDA-NRCS on June, 25, 1997.

Dr. Halvorson participated in the USDA-ARS Global Climate workshop held in Temple, TX September 22-25, 1997.

Dr. Halvorson presented a paper at the 1997 ASA-SSSA-CSSA Annual meetings in Anaheim, CA, October 26-30, 1997 entitled "Winter wheat response to tillage, N, and precipitation under annual cropping".

Dr. Halvorson served as an advisor to the Board of Directors of the Manitoba-North Dakota Zero Tillage Farmers' Association during 1997, assisting with the educational program for the 1998 Zero Tillage Workshop held in Minot, ND, Feb. 2-4, 1998. In addition, he served on the educational committee for the Association which produced the new "Zero Till Manual: Advancing the Art" that was released by the Manitoba-ND Zero Tillage Farmers' Association in January 1997. The USDA-ARS research from the Area IV SCD-ARS Research Farm at Mandan was an integral part of the new manual. A video was also produced that presents the highlights of the

manual. More than 10,000 copies of the manual were printed for distribution to farmers, agribusiness, public and private agencies, and interested public in Manitoba, North Dakota, and other locations in the U.S. and the World (1000 copies sent to Australia). This manual is expected to have a major impact on adoption of no-till or zero-till practices world wide.

Dr. W.J. Hunter:

Dr. Hunter supplied information on his research with the use of vegetable oil to bioremediate high nitrate water and on the soybean inoculum to the news media and to individuals, companies and communities. Two popular press news articles are "in press". One for ARS Quarterly and the other for Farm Journal.

Commercial sales by Urbana Laboratories of a legume bacterial inoculant developed by Drs. Hunter and Kuykendall (ARS Beltsville) continued in 1997. In the past three years enough inoculum has been produced to treat over 1,200,000 acres of soybean and to have had an economic impact of over $14,000,000.

Dr. G.L. Hutchinson

Dr. Hutchinson serves on the Biogenic Emissions Committee for the Emission Inventory Improvement Program sponsored by the State and Territorial Air Pollution Program Administrators, Association of Local Air Pollution Controls Officials, and the U.S.E.P.A. Its purpose is to provide agencies with the necessary tools to prepare consistent, reliable emission inventories through the adoption of standardized procedures.

Dr. Hutchinson was invited to attend and present the keynote lecture entitled "Understanding and modeling soil-atmosphere gaseous N oxide exchange processes" at the Workshop of Greenhouse Gas Research in Agriculture, March 12-14, 1997, Sainte-Foy, Québec, Canada.

Dr. Hutchinson was invited by convener Sheo Prasad to participate, chair a technical paper session, and present a critical review of "Processes for production, consumption, and atmospheric exchange of biospheric gaseous N oxides" at a special symposium entitled Atmospheric Sources and Sinks of Nitrous Oxide and Their Implications at the spring meeting of the American Geophysical Union, May 27-30, 1997, Baltimore, MD.

Dr. Hutchinson serves as an advisor to, and cooperator with, projects of the UC Davis Center for Ecological Health Research.

Dr. A.R. Moiser

Dr. Mosier was Editor of a special issue Volume 48, Nos. 1-2, 1997, in Nutrient Cycling in Agroecosystems. NO_x Emissions from Soils and its Influence on Atmospheric Chemistry.

Dr. Mosier was Chair of the editorial panel for special issue Volume 49, Nos. 1-3, 1997, in Nutrient Cycling in Agroecosystems. Soil-Source and Sink of Greenhouse Gases.

Dr. Mosier was Chair of the editorial committee: volume in press to be published in early 1998, in Nutrient Cycling in Agroecosystems. Ammonia Emissions from Agriculture.

Dr. Mosier was a member of the organizing committee and participant in a SCOPE N Workshop, "The Effect of Human Disturbance on the Nitrogen Cycle in Asia" that was held in Nanjing China, October 12-19, 1997.

Dr. Mosier was a member of organizing committee and participant in an International Workshop on "Dissipation of N from the Human N-cycle, and its Role in Present and Future N_2O Emissions to the Atmosphere" that was held in Oslo, Norway, May 22-25, 1997.

Dr. Mosier was a Keynote speaker for the 11th World Fertilizer Congress of the International Scientific Center of Fertilizes that was held in Gent, Belgium September 7-13, 1997.

Dr. Mosier was a member of Steering Committee for the Intergovernmental Panel on Climate Change (IPCC) Expert Group Meeting: Comparison of Top-down with Bottom-up Greenhouse Gas Emission Inventories.

Dr. Mosier was the Chair of sessions on N_2O at the IPCC Expert group meeting on Methods for the Assessment of Greenhouse Gas Emission Inventory Quality that was held in Bilthoven, The Netherlands November 5-7, 1997.

Dr. Mosier was a member of proposal review panel for the USDA Cooperative State Research, Education, and Extension Service Fund for Rural America, Environment Panel, October 5-8, 1997, Snow Bird, Utah.

Dr. Mosier was elected as Liaison Officer and member of the Presidium of the International Scientific Center of Fertilizers.

Dr. Mosier and Dr. Dennis Ojima (Colorado State University) were Coorganizers, of a trace gas synthesis workshop conducted in cooperation with the National Center for Ecological Analysis and Synthesis, Santa Barbara, California, December 2-6, 1997.

Dr. Mosier is Chair of the Steering Committee for U.S. Trace Gas Network (TRAGNET).

Dr. Mosier provided three months training in ^{15}N technology to Ms. Yulnafatmawita Lamsuddin from the Agricultural Faculty of Andalas University, Padang, West Sumatra, Indonesia. This training was funded by the International Atomic Energy Agency.

Dr. Mosier continues providing technical advise in isotope and trace gas methodologies within a collaborative project with Dr. Sakorn Phongpan from the Thailand Department of Agriculture, Bangkok, Thailand.

CALIBRATION OF NLEAP FOR THE SAN LUIS VALLEY WATER QUALITY PROJECT

J.A. Delgado and R.F. Follett - Co-Investigators: M. Schaffer[1], M. Brodahl[1] and R. Riggenbach[2]

PROBLEM: In different studies conducted during the last 10 yr, underground well water nitrate concentrations (NO_3-N) have been found to be higher than 10 mg NO_3-N L^{-1} for some areas of the San Luis Valley (SLV) of south central Colorado. Nitrogen fertilizer use, high water table and sandy soils have been attributed as factors that contribute to NO_3-N leaching in the SLV.

APPROACH: USDA-ARS and USDA-NRCS have been using NLEAP (Nitrate Leaching and Economic Analysis Package), as a computer software package, capable of providing an assessment of farm management practices on the transport of NO_3-N in and out of the root zone of shallower root crops such as lettuce (*Lactuca sativa L.*) and potato (*Solanum tuberosum L.*) and deeper rooted crops such as winter cover crops that are grown in the SLV. A new version of NLEAP capable of evaluating not only the residual soil NO_3^--Non the root zone of each crop, but also the residual soil NO_3^--N based on a baseline layer similar for the whole system was needed. Using data collected at 25 sites, a new version 1.2 of the NLEAP model was developed.
The new NLEAP 1.2 version can simulate the residual soil NO_3^--N for three layers, 0 - 0.3 m, 0.3 m to bottom of the root depth (BRD), and BRD to a baseline. This baseline can be set from a minimum of 0.3 m to a maximum of 1.5 m, by 0.03 m increments. The baseline can also be set to be equal to the bottom of the root depth. The 1.2 version also simulates NO_3^--N leaching from the BRD and from the baseline. Another new feature in the NLEAP 1.2 version is that the maximum root depth can be entered to the nearest 0.03 m, from a minimum root depth of 0.3 m to a maximum of 1.5 m. Previously for the NLEAP 1.10 version, maximum root depth was entered to the nearest 0.3 m increment, (e.g. 0.3, 0.6, 0.9, 1.2, or 1.5 m). The last new feature of the NLEAP 1.2 version is that it can simulate for a single year two crops with different rooting depths.

RESULTS: NLEAP simulations showed: a) N use efficiency in small grain > potato > lettuceb) rotations of small grains with potato and lettuce and proper management of irrigation, increases efficiencies in these systems; and c) wheat (*Triticum aestivum L.)* and rye (*Secale cereale L.)*, when used as winter cover crops (WCC), mitigate N losses by scavenging N that has been lost from the shallower root systems of lettuce and potato. NLEAP is a useful tool in evaluating the effects of spatial variability such as soil texture, soil coarse fragments and residual soil NO_3^--N observed in the field. This new technology transfer tool (NLEAP 1.2) can be used by extension agents, farmers, educators, and scientists to conduct assessments of the effects of best management practices on conservation of water quality and N budgets in the SLV and in other areas of the USA.

FUTURE PLANS: The validation/calibration effort will continue across different cropping systems, different soil textures and agricultural practices conducted in the SLV. Final data describing the results from the calibration/validation processes will be published.

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[1] USDA-GPSR, Fort Collins, CO.
[2] USDA-NRCS, San Luis Valley Water Quality Demonstration Project, Monte Vista, CO.

POTENTIAL USE OF CONTROLLED RELEASE FERTILIZER FOR CONSERVATION OF WATER QUALITY IN THE SAN LUIS VALLEY OF SOUTH CENTRAL COLORADO

J.A. Delgado and A.R. Mosier - Co-Investigators: A. Kunugi[1] and L. Kawanabe[2]

PROBLEM: Vegetable crops with shallow root systems such as potato (*Solanum tuberosum* L.), are grown in the San Luis Valley. Once the N fertilizer (NF) moves out of the root zone it is not available for uptake during the growing season. The potential to use controlled release fertilizers (CRF) as a method of increasing NF use efficiency (NFUE), and reduce NO_3^--N leaching is being studied.

APPROACH: In May of 1997, potato was planted on a center-pivot irrigated Mosca loamy sand. Different rates of N applications of Polyon®[3] coated urea (P) and Meister®[3] coated urea (M) were compared to farmers' traditional practices (F) of 269 kg N ha^{-1} (F269). Three rates of NF for P and M were broadcast and incorporated into the potato hill, at planting. For the 3 N rates we included 29 kg urea-N ha^{-1} as a starter for a total of 134, 202 and 269 kg N ha^{-1}. Control plots or zero NF were also established.

Table 1. Effect of treatments on yield. Tuber compartments according to weight were: a) tubers > 227 g (cartons); b) 114 to 227 g (strippers); and c) 28 to < 114 g (seed).

Trt[a]	---Yield[b] by compartments---			Total
	Seed	Strippers	Cartons	Yield[b]
	--------- Mt ha^{-1} ----------			Mt ha^{-1}
Ctr	10.2 a	14.0 b	3.1 c	27.3 c
M134	9.9 a	26.7 a	9.6 b	46.1 ab
M202	8.3 a	22.4 a	9.4 b	40.1 b
M269	9.9 a	22.0 a	15.9 a	47.4 a
P134	13.7 a	22.2 a	9.2 b	45.0 ab
P202	8.1 a	24.0 a	14.3 ab	46.4 ab
P269	9.4 a	21.7 a	17.0 a	48.2 a
F269	7.4 a	21.3 a	16.8 a	45.5 ab

[a] Treatments are control (Ctr), MEISTER (M), POLYON (P), and farmers practices (F).
[b] Within a compartment (column), treatments with different letters are different at LSD, P<0.05.

RESULTS: Yield for cartons, strippers and seed with one application of P269 and P202 kg N ha^{-1} were no different than the 10 split applications with F269($P<0.05$) (Table 1). Yield for cartons, strippers and seed with M269 kg N ha^{-1} were no different than F269 ($P<0.05$). The M134 and P134 at ½ farmers' NF rate were not different in total tuber yield from the F269 ($P<0.05$). However the M134 and P134 treatments did not produce as many large tubers as the M269, P269 and F269. These initial results suggest that there is a potential to use CRF to reduce N inputs while maintaining yields, to increase NFUE and protect water quality.

FUTURE PLANS: Data about plant N uptake, N use efficiency and transport of NO_3^--N in the soil profile is currently being analyzed. Additional CRF studies will be conducted during 1998.

[1] San Luis, Alamosa, CO
[2] USDA-NRCS, San Luis, Alamosa, CO
[3] Manufacturers names are necessary to report factually on available data, however the USDA neither guarantees nor warrants the standard of the product; and the use of a given name by the USDA does not imply approval of that product to the exclusion of others that may be suitable.

SOIL QUALITY STUDIES AND THEIR RELATIONSHIP TO WATER QUALITY IN THE SAN LUIS VALLEY OF SOUTH CENTRAL COLORADO

J.A. Delgado - Co-Investigator: R.T. Sparks[1]

PROBLEM: In cropping areas of the San Luis Valley (SLV), potential wind erosion is greater in the spring, especially after harvesting of vegetables crops such as potato (*Solanum tuberosum* L.) that leave small amount of crop residue in the surface soil. The inclusion of barley (*Hordeum vulgare* L.) or wheat (*Triticum aestivum* L.) in a potato-grain rotation increases the amount of crop residue returned into the soil. Grains also reduce potential wind erosion. Disturbed rangeland areas of the SLV are susceptible to potential wind erosion that can change soil chemical and physical properties. Our objectives were: a) conduct an assessment of the effects of incorporation of grain crops in a potato-grain rotation and its effects on soil and water quality; and b) to determine the effects of plant species on soil quality of disturbed rangelands.

APPROACH: We selected four sites, with similar agricultural practices and soil type that two decades ago were converted from rangeland into cultivated center pivot irrigation sprinklers. The main variability in crop management at these sites have been the amount of straw returned into the surface soil. At each site, soil samples were collected in the cultivated area and in adjacent rangeland. The rangeland dominating plant species was black greasewood (*Sarcobatus verniculatus*). Less than 1% of the area was in alkali sacatone grass (*Sporobulus airoides* Torr.) and a significant area was bare soil (range: 34.4 -53.8%). Soil samples were collected under greasewood, grass, and bare soil areas.

RESULTS: Comparisons within cultivated sites show that soil organic matter (SOM) content increased with greater amounts of straw returned into the system ($P<0.05$). Soil organic carbon ($P<0.01$) and soil organic nitrogen ($P<0.10$) were correlated with the amounts of straw returned into the fields. The losses of fine particles such as silt and clay are reduced by the incorporation of grains into the crop rotation ($P<0.05$). Soil organic matter (SOM) and microbial biomass carbon were greater in the greasewood area than in the grass or bare soil areas ($P<0.05$). The SOM and microbial biomass carbon was higher in the grass than in the bare soil area ($P<0.05$). The surface soil under the greasewood had significantly higher concentrations of nutrients such as phosphorus, zinc, iron, manganese, and copper ($P<0.01$). The sand content was higher and the fine particles were lower in the bare soil areas when compared to the greasewood and grass areas ($P<0.05$). Our data suggest that greasewood and/or grass help to sequester atmospheric carbon and that bare soils are susceptible to losses in SOM and fine particles due to wind erosion. Crop management practices have the potential to be used as tools to protect soil and water quality and increase the sustain ability of the intensive agriculture of sandy soils of the SLV.

FUTURE PLANS: These studies in the relationship between crop management and soil and water quality in the SLV will continue and manuscripts will be published.

[1] USDA-NRCS, Area Office, Alamosa, CO

SOIL-C STORAGE WITHIN SOIL-PROFILES OF THE HISTORICAL GRASS LANDS OF THE USA.

R.F. Follett and E.G. Pruessner - Co-Investigators: Kimble[1] and S. Samson-Liebig[1]

PROBLEM: Vast reserves and the potential to sequester immense amounts of carbon (C) in soils exists in the historical grasslands (HG) of the USA. These soils are important as a source-sink in global C cycling. Large areas within the HG have been converted from cropland to the Conservation Reserve Program (CRP). Research indicates that CRP enhances C sequestration, but the magnitude is uncertain as is the importance of C gains or losses at deeper soil-profile depths. Another consideration is that CRP contracts are beginning to expire; millions of hectares of CRP land may return to production. Thus, much of the C that the CRP program helped sequester is at risk to being recycled back to the atmosphere as CO_2.

APPROACH: A collaborative effort is underway with the National Soil Survey Laboratory (NSSL) of the NRCS in Lincoln, NE to collect detailed soil-profile measurements. Use of these data, with STATSGO and other data bases, will allow estimates of soil-C storage in HG soils and the influence of management (cropped vs. CRP vs. native grassland). Soils are sampled by horizon from pits (~ 2m deep) at sites along precipitation and temperature gradients. At every site, a separate pit is sampled for each of the three managements; all pits are in the same map unit and on a similar geomorphic setting, even though soil series may change because of management. Soil-physical, -mineralogical, -micromorphological, and -chemical characterizations are by the NSSL. Our laboratory measures various C pools (i.e. total soil-organic carbon (SOC), identifiable plant material (IPM), particulate organic matter, mineral associated organic C, and microbial biomass-C).

RESULTS: Sites have been sampled in CO, NE, IA, TX, MT, MO, MN, OK, and ND and the samples are at various stages of analyses. For sites in CO, NE, IA, TX, MT, MO, and MN that had been in CRP for at least 5yr, average SOC in the 0-5cm depth compared to paired cropped sites, had increased 2750 kg/ha ($P<0.05$). At these same sites, average IPM (0-10cm depth) was 2640 kg/ha greater ($P<0.01$) than at cropped sites. The CRP sites (0-10cm depth) averaged 8000 kg/ha ($P<0.05$) less SOC and 400 kg/ha ($P>0.10$) less IPM than paired native sites. The increased amounts of IPM under CRP is important to the rebuilding and sequestration of SOC under CRP and the amounts of IPM approach those observed under paired native sites. There are also increases in organic C in the top 10 cm in CRP versus cropland, though they have not reached the levels of the native soil. The near surface nature of recently sequestered SOC emphasizes the importance of the protection of surface soil from soil erosion.

FUTURE PLANS: Field collection of samples is completed. The focus is now to complete the laboratory analyses and pursue data analyses, interpretation and publication.

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[1]NRCS; Lincoln, NE

USE OF IMPROVED TILLAGE SYSTEMS TO INCREASE SOIL ORGANIC CARBON AND NITROGEN USE EFFICIENCY IN VERTISOLS IN MEXICO

R.F. Follett and E.D. Buenger - Co-Investigators: J.V. Castellanos[1] and M. Mora[1]

PROBLEM: Vertisols are a major soil around the world and in parts of the United States. In Mexico, vertisols occupy about one million hectares and produce about one fourth of the wheat and one fifth of the corn and sorghum. In Mexico, crop residues have been burned and the soils deeply and frequently plowed for over 50 yrs. This traditional practice has reduced soil organic carbon (SOC) by half. As a result the soils have lost much of their capacity to mineralize N (soil N supplying capacity is about 16 kg N/ha per crop), microbial biomass for nutrient retention and cycling, and water holding capacity. Additionally, nitrate that has been leached into groundwater used by rural residents for drinking water often exceeds recommended health standards.

APPROACH: This project was funded by the Research and Scientific Exchanges Division of USDA/FAS/ICD. A collaborative effort is underway to demonstrate that soil organic matter levels can be increased in the vertisols of the center of Mexico by the use of no-till for wheat-corn and wheat-bean cropping sequences. $^{15}N/^{14}N$ and $^{13}C/^{12}C$ isotope-ratio technology will be used to study the effect of traditional versus improved tillage on N and SOC dynamics. The experiment is on 10 m by 10 m irrigated plots (2 crops/year) and consists of 4 replications of 3 fertilizer rates (0, 150, and 300 kg N/ha) and 5 tillage treatments; the 5 tillage treatments are wheat-corn with no-till, wheat- corn with plowing, wheat-corn with burning of the residues, wheat-bean with no till, and wheat-bean with plow tillage. The rates of ^{15}N-labeled fertilizer were applied once, just prior to winter wheat emergence.

RESULTS: Residue burning produced higher yields than for both conventional and conservation tillage under the lower rates of N fertilization. Therefore, at this stage of the experiment and at low fertilization levels, N immobilization takes place at the beginning of the season and by the time the N is released its benefits to the crop are less. At higher levels of N, yield response was largest for the residue incorporation treatment, followed by residue burning, and then no-till. At high levels of N, differences in grain yield between the tillage/residue management treatments were not significant ($P<0.05$). Residual soil nitrogen derived from ^{15}N labeled fertilizer (Ndff) was measured after harvest. Ndff (0-120cm depth) was greatest under treatments where crop residues were incorporated or burned. No-till treatments had the lowest Ndff. These results indicate residue management has a large effect on N availability to the crop and will also influence sequestration of residue C into soil organic matter.

FUTURE PLANS: This study will be continued through at least one more crop cycle and plant and soil samples collected for laboratory analyses.

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[1]Campo Experimental Bahio Celaia- San Miguel Allende, MX

ORGANIC CARBON STORAGE IN HISTORIC U.S. GRASSLAND SOILS

R.F. Follett and E.G. Pruessner - Co-Investigators: J. Kimble[1], S. Samson-Liebig[1] and S.W. Leavitt[2]

PROBLEM: Vast reserves and the potential to sequester immense amounts of carbon (C) in soils exists in the historical grasslands (HG) of the USA. These soils are important as a source-sink in global C cycling. This study considers the role of soil for long-term sequestration of carbon (C) as it may relate to its exchange with atmospheric CO_2, a greenhouse gas.

APPROACH: A collaborative effort is underway with the National Soil Survey Laboratory (NSSL) of the NRCS, the University of AZ, and the Soil-Plant-Nutrient Research Unit to carbon date and use other carbon-isotope measures to evaluate both how much and how long soil-organic carbon (SOC) is stored in HG soils in the United States. Native grassland soils in CO, NE, IA, TX, and MT were sampled by horizon from pits to a depth of about 2 m at sites along precipitation and temperature gradients. Soil-physical, -mineralogical, -micromorphological, and -chemical characterizations are by the NSSL. Our laboratory measures various C pools, including SOC and processes the samples for ^{14}C dating. The soil samples are then ^{14}C dated at the Univ. of AZ. Besides the sampling sites indicated above, soil samples from native grassland sites have also been collected from locations in MO, MN, OK, and ND to be added to this data set.

RESULTS: The results from native grassland sites along the precipitation and temperature gradients across CO, NE, IA, TX, and MT showed that nearly one-half of the total weight of soil-organic C (SOC) is in the top 20 cm and up to one-third can be in the top 10 cm of soil. The remaining one-half is located from 20 to 200 cm below the surface. Weight of SOC was between 85 to 150 t ha^{-1} in the top 2 m of soil. These data show the importance of protecting near-surface soil and its associated SOC from loss. ^{14}C dating of soil C indicates that the one-half of the SOC that is sequestered below 20 cm has mean residence times (MRT) that are greater than 1000- to 2000-y. Soil C at depths of about 2 m has MRT of 9000- to 13000-y, but accounts for only about five percent of the total. Thus, once sequestered, immense amounts of SOC remain in soil profiles for a very long time.

FUTURE PLANS: Processing and analyses of soil samples that have been collected from locations in MO, MN, OK, and ND will be completed and added to this data set. Then our focus will be the analyses, interpretation, and publication of the data.

[1] NRCS; Lincoln, NE
[2]University of Arizona, Tucson, AZ

EARLY SEASON MEASURES OF WINTER WHEAT YIELD POTENTIAL

R.F. Follett and A.D. Halvorson - Co-Investigators: C.E. Reule[1] and G.S. McMaster[2]

PROBLEM: Satisfying nitrogen (N) requirements of winter wheat is important for maximizing crop yields and high economic returns to farmers. Fertilizer-N needs of winter wheat are customarily met by fall fertilization. However, spring fertilizer-N application has the advantages of allowing time to evaluate springtime soil moisture, crop stand, pests, and other conditions; to obtain spring soil and plant-tissue analyses; to consider split-N application fertilizer needs and other production costs; and to evaluate yield potential and market conditions before expending money required to purchase and apply fertilizer N.

APPROACH: A three year no-till experiment with winter wheat (*Triticum aestivum* L.) was conducted near Akron, CO on a Platner loam (fine, montmorillonitic, mesic Aridic Paleustoll) to determine the effectiveness of using early-season measures for N-fertilizer management in the Central Great Plains of the USA. A randomized complete block with three replications was used. Ammonium nitrate (33-0-0) was broadcast applied separately to fall and spring fertilized plots at rates of 22.4, 44.8, 67.2, and 89.6 kg N ha^{-1}. The "N-rate study" part of the experiment received either fall-N, applied immediately before planting, or spring-N, at pre-jointing (Feekes growth stage 5), applied immediately following spring soil and plant tissue sampling. The "split application study" part of the experiment received rates of 44.8, 67.2, and 89.6 kg N ha^{-1} that were split, in increments of 22.4 kg N ha^{-1}, between fall (before planting) and spring (following plant and soil sampling) to compare the timing of applied fertilizer-N. Plant and soil tests included chlorophyll meter readings, leaf-N, stem NO_3-N, soil NH_4-N, soil NO_3-N, weight of 20 leaves, and number of culms m^{-2}.

RESULTS: Our results largely agree with the interpretation of plant (leaf-N concentration) and soil (NO_3-N plus NH_4-N) tests of previous authors. However, we did not show the need to measure early-season soil-test NH_4-N, only soil-test NO_3-N. Chlorophyll meter and leaf-N concentrations had the greatest potential for predicting spring-N fertilizer needs. Stem NO_3-N was responsive to fertilizer-N rates, but not definitive to recommend spring-fertilizer N. Weight of 20 leaves was most responsive to fraction of fall-applied fertilizer N rather than total fertilizer-N. Spring-applied N was equal to fall-applied N for grain yield. Chlorophyll meter readings and leaf-N were highly correlated to fall-applied fertilizer N rates. Testing data from the N-rate study against spring N-application rates from the split application study indicate a high degree ($r^2 \simeq 0.75$) of predictability for improved recommendations for spring fertilizer-N that may increase both fertilizer-N use efficiency and economic returns.

FUTURE PLANS: Field collection of samples is completed. The focus is now to pursue data analyses, interpretation and publication.

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NITROGEN FERTILIZER UPTAKE AND NITROGEN USE EFFICIENCY OF IRRIGATED CORN

R.E. Godin[1], R.F. Follett[2], D.G. Westfall[1], H.R. Duke[2] and E. Cardon[1]

PROBLEM: Fertilizer nitrate nitrogen (NO_3-N) that remains in the soil after corn cropping is subject to leaching and could contaminate groundwater. Therefore, it is important to determine fertilizer N-use efficiency and also what portion of applied fertilizer N is taken up by irrigated corn.

APPROACH: A nitrogen x irrigation intensity field study was conducted using ^{15}N label N fertilizer to determine the N uptake by corn and calculate N use efficiency. Microplots were established with the main plots of a larger study and fertilized with ^{15}N labeled fertilizer at the identical N application rate as the main plots. The study was a split plot design with the irrigation rate as the main effect and included four N application rates of 0, 67, 135, and 202 kg N ha^{-1} with three labeled ^{15}N rates of 67, 135, and 202 kg N ha^{-1} and three irrigation intensities of 85, 105, and 125% of calculated evapotranspiration (ET). A recommended N application rate of 135 kg N ha^{-1} was determined using the Nebraska algorithm and based on 60 kg N ha^{-1} in the recommended soil sampling depth of 60 cm. The 67 and 202 kg N ha^{-1} were used to represent deficient and excessive rates respectively. The ET was calculated using a modified Penman equation with an on-site weather station. The original target irrigation rates were 70, 100, and 130% ET, however, high in-season precipitation (28 cm) resulted in the adjusted irrigation rates mentioned above.

RESULTS: Highest total N uptake (TNU) was at the higher N rates for all three irrigation rates, with N rate having a significant effect on TNU ($P< .05$). Average TNU ranged from 186 kg N ha^{-1} at zero N applied to 223 kg N ha^{-1} at 135 kg N applied ha^{-1}. The relatively small difference in TNU across treatments are probably due to high residual NO_3-N in the 0-120 cm profile of 210 kg N ha^{-1}. Although TNU was highest at the higher N rates, this did not translate into higher grain yields probably due to an early freeze at the R5 growth stage which did not allow the corn to reach maturity at R6. Grain yields ranged from 10 Mg ha^{-1} with zero N applied ha^{-1} to 12 Mg ha^{-1} at 135 kg N applied ha^{-1}. Whole plant N derived from fertilizer on a weight basis (kg Ndff) was significantly affected by N rate across all three irrigation treatments. The Ndff increased with increasing N rate from 35 kg N ha^{-1} at 67 kg N applied ha^{-1} to 98 kg N ha^{-1} at 202 kg N applied ha^{-1}. All treatments show a Ndff of approximately 50% of N applied. The % fertilizer N recovered in the grain was significantly affected by both irrigation and N application rate. The highest % fertilizer N recovered in the grain with regard to irrigation intensity was 37% at 85% ET and the lowest of 33% at 125% ET. The % fertilizer N recovered in the grain at the 105% ET rate was not significantly different from the 85% or the 125% ET rates. We recommend that the prescribed soil sampling depth for residual soil N be increased to include the whole crop root zone to more closely calculate N application rate and reduce the possibility of leaching residual soil NO_3-N.

FUTURE PLANS: Determine corn uptake of residual soil ^{15}N fertilizer from first year ^{15}N application in a subsequent corn crop and for a N budget under irrigated corn.

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CROPPING SYSTEM, TILLAGE, AND NITROGEN FERTILITY STUDY

A.D. Halvorson - Co-Investigators: J. Krupinsky[1], S. Merrill[1], D. Tanaka[1] and B. Wienhold[2]

PROBLEM: Adoption of minimum-till (MT) and no-till (NT) has improved precipitation storage efficiency which increases the potential to crop more intensively than the traditional crop-fallow dryland system of farming. Increasing cropping intensity requires a higher level of N inputs to optimize yield potential. Crop management information is limited on the success of annual cropping systems using reduced tillage. This study evaluated the potential of annual cropping in the Northern Great Plains with conventional-till (CT), MT, and NT systems compared to spring wheat fallow (SW-F). Nitrogen (N) fertility needs were evaluated for optimization of yield potential.

APPROACH: Two dryland cropping systems [SW-F and spring wheat-winter wheat-sunflower (SW-WW-SUN)], three tillages (CT, MT, NT), three N fertilizer levels (0, 22.4, and 44.8 kg N/ha for SW-F and 33.6, 667.2, and 100.8 kg N/ha for SW-WW-SUN) and two varieties of each crop were studied from 1985 through 1996. In 1997, cultivar plots were terminated and one 2-year rotation [spring wheat-Pea (SW-P)] replaced one cultivar treatment of the original SW-F system. One 3-year rotation [spring wheat-corn-pea (SW-C-P)] replaced a cultivar treatment of the original SW-WW-SUN rotation. Grain yields were collected in 1997 as the first year of new treatments were established. Because of a buildup of residual soil N, no fertilizer was applied to the 2-year rotation plots and only 33.6 kg N/ha to the 3-year rotation plots in 1997.

RESULTS: Despite drought conditions during the growing season (only 13 cm precipitation, May-August), spring wheat yields were average (2150 kg/ha) in SW-F in 1997 due to a soil profile full of water and timely rains at critical growth stages with no significant responses to tillage or N fertilization. Spring wheat yields in the SW-P rotation averaged 2204 kg/ha with no significant responses to tillage or N treatments; however, tillage affected pea yields with NT>MT>CT. NT pea yield was 1646 kg/ha. Forage yields were 3827, 3541, and 2498 kg/ha for NT, MT, and CT, respectively. In the SW-WW-SUN rotation, spring wheat did not respond to tillage or N in 1997 with an grain yield of 2090 kg/ha. Winter wheat yields were 1344 kg/ha for NT, 739 kg/ha for MT, and 759 kg/ha for CT. Sunflower yields averaged 2362 kg/ha with MT>NT>CT. Sunflower responded to residual N level. In SW-C-P rotation, spring wheat yields averaged 2258 kg/ha with no response to tillage and N level. Corn silage yields averaged 16.7 t/ha at 70% moisture. Corn grain yields were affected by tillage with NT yielding 2710 kg/ha, MT 2120 kg/ha, and CT 1637 kg/ha at 15.5% moisture. Pea yields averaged 1633 kg/ha at 13% moisture and forage yield was 3873 kg/ha at 0% moisture.

FUTURE PLANS: The 1985 through 1996 data are being summarized and prepared for publication. The cooperators will continue the study in 1998.

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ROW SPACING EFFECTS ON SUNFLOWER GRAIN YIELD IN A NO-TILL SYSTEM

A.D. Halvorson

PROBLEM: Narrowing the row spacing of sunflowers from the traditional 76 or 91 cm row spacings to less than 51 cm would allow producers to potentially utilize small grain drills for seeding sunflower. In addition, Dr. Tanaka demonstrated in 1995 that narrowing row spacing from 76 cm to 38 cm significantly reduced weed biomass in sunflower plots. Limited information is available on the effects of narrow row spacing on sunflower yields in minimum-till and no-till systems. Farmers, the National Sunflower Association, Sunflower Seed Companies, and Federal Crop Insurance have shown a great deal of interest in narrow row spacing sunflowers. Therefore, this study was initiated to evaluate the effects of row spacing (76, 38, and 19 cm) on sunflower yields and oil content, and to visually observe the effects of row spacing on weed competition within sunflowers.

APPROACH: In 1997, two sunflower cultivars (DeKalb 3790 and Pioneer 6150) were seeded in 19, 38, and 76 cm rows in a replicated study. The 19 cm rows were planted with a JD 750 no-till disk drill at a population of about 69,160 seeds/ha. The 38 and 76 cm rows were planted with a JD MaxEmerge II row crop planter at 69, 160 seeds/ha. The sunflowers were planted no-till into standing barley stubble on May 27, 1997. On May 30th, Roundup Ultra was applied. No other herbicides were applied because of drought conditions. The plots were aerial sprayed with Asana on August 10, 1997. The plots were infected with sunflower midge which cause considerable damage to the Pioneer 6150 cultivar. N fertilizer was band applied as liquid UAN (28%) at a rate of 90 kg N/ha at seeding in the 38 and 76 cm row spacings. N (90 kg N/ha as urea) was banded between the rows in the 19 cm row spacing plots seeded with the JD 750 drill.

RESULTS: Weeds were not a problem until late July because of drought during the early part of the growing season. A late flush of weeds develop as in previous years. The 76 cm row plots were heavily infested with weeds, with less weeds in the 38 cm row plots, and few weeds in the 19 cm row plots. This is consistent with observations made in 1995 and 1996. Grain yields were significantly different between sunflower cultivars. A contributing factor to the significantly lower yield of the Pioneer 6150 was the damage caused by the sunflower midge. When averaged over cultivars, row spacing did not have a significant affect on grain yield in 1997. However, DeKalb 3790 did show trends of an 8% and 17% increase in yield with the 19 and 38 cm row spacings, respectively, when compared to the 76 cm inch row spacing. When averaged over two years, the 19 and 38 cm row spacing plots had significantly higher yields (12 to 14%) than the 76 cm row spacing plots.

FUTURE PLANS: The two year results will be prepared for a summary article in the Sunflower magazine. The study will not be continued in 1998.

ROW SPACING EFFECTS ON CORN GRAIN YIELD IN A NO-TILL SYSTEM

A.D. Halvorson

PROBLEM: Narrowing the row spacing of corn from the traditional 76 cm row spacing to less than 60 cm would allow producers to potentially utilize small grain drills for seeding corn. In addition, research has shown that narrowing row spacing from 76 cm to 38 cm significantly reduced weed biomass in the sunflower fields. Limited information is available on the effects of narrow row spacing on dryland corn yields in no-till systems in the Northern Great Plains. Farmers are showing a great deal of interest in narrow row spacing because of the potential to utilize small grain equipment for seeding rather than row crop planters. Therefore, this study was initiated to evaluate the effects of row spacing (76, 38, and 19 cm) on corn yields and to visually observe the effects of row spacing on weed competition within the corn.

APPROACH: Corn, P3893, (88 day corn) was planted in 19, 38, and 76 cm rows at a population of 39,520 seeds/ha in a replicated study on May 15, 1997. The 38 and 76 cm treatments were planted with a JD MaxEmerge II air planter equipped to plant both row spacings. The 19 cm row spacing treatment was also planted with a JD MaxEmerge II planter by making a second pass and splitting the 38 cm rows. This worked only fair with considerable variation in distance between rows. We chose this option in an attempt to achieve uniform seeding rates between all row spacings. In 1996 we used a JD750 no-till drill that had been calibrated in a stationary position, but we ended up with a higher seeding rate than with the MaxEmerge II planter. The corn was planted no-till into 1996 spring wheat stubble. Because of drought conditions, a preplant residual herbicide was not applied. The corn field was sprayed with Accent + Buctril on June 11, 1997. The plot area was not sprayed prior to planting or immediately after planting with Roundup because few weeds were visible. Fertilizer, 101 kg N/ha as 28% liquid UAN was banded beside the row at planting. Mid- to late-season weed control was poor in 1997. The corn plots were harvested on October 19, 1997 with no need for grain drying due to the dry summer conditions.

RESULTS: Visual differences in weed competition would be for a slight reduction in weed competition in the 19 and 38 cm rows over that of the 76 cm rows. Grain yields were higher for the narrow row spacings when compared with 76 cm row spacing. Grain test weights were excellent in 1997. The soil profile was at field capacity moisture content at planting. Although rain fall was minimal, it was timely which helped corn grain yields in 1997. The 1997 data support the 1996 observations of higher yields with the 19 and 38 cm row spacings than with 76 cm row spacing. The two year average grain yield was 7363, 7012, and 5639 kg/ha for the 19, 38, and 76 cm row spacings, respectively. These data indicate a need to continue looking at the use of narrow row spacing for dryland corn production in NT systems in the Northern Great Plains. The two year average corn yields are very encouraging for inclusion of corn in dryland rotations.

FUTURE PLANS: The study will be terminated in 1998 and results summarized for possible publication as a popular article.

EVALUATION OF SITE-SPECIFIC FARMING TECHNOLOGIES FOR DRYLAND CROP PRODUCTION

A.D.Halvorson - Co-Investigators: V. Hofman[1], D. Franzen[1] and J. Krupinsky[2]

PROBLEM: Development of variable rate chemical application technology, yield monitors for combines, global positioning systems (GPS), and graphic information systems (GIS) provides the opportunity to manage soils rather than fields. This technology appears to be economically feasible for high cash value crops and for some irrigated crops. Little information is available on the feasibility of using this technology for dryland crops in semiarid areas such as western North Dakota where profit margins are small. Therefore this study was initiated to evaluate the potential for using site-specific farming technologies for dryland farming systems in semiarid areas of the Northern Great Plains. Specific objectives were: 1) evaluate the potential for using site-specific technologies to manage nutrient applications in semiarid areas; 2) develop soil sampling and fertilizer management practices to improve nutrient use efficiency and cost effectiveness of site-specific farming technologies for dryland conditions; and 3) evaluate the influence of site-specific technology utilization on crop yields, environmental quality, and economic sustainability.

APPROACH: In 1995, three fields of approximately 20-30 acres in size with varying topography were established for this study using a spring wheat-winter wheat-sunflower rotation. In 1995, GPS was installed with a yield monitor on a combine. Yields have been mapped for three years in each field. Soil samples have been collected at 33.5 m grids in one field and at 45.7 m grids in two fields to evaluate changes in soil chemical properties (N, P, K, Cl, Zn, S, pH) and to help determine N and P fertilizer needs. Surface topography was also measured so that nutrient levels can be related to topography. N and P fertilizer rates are adjusted on-the-go during seeding operations based on soil test values and yield goals.

RESULTS: The 1997 wheat yields varied from 336 kg/ha to over 3700 kg/ha with an average winter wheat yield of 1882 kg/ha and an average spring wheat yield of 2486 kg/ha. Sunflower yields ranged from 560 to over 3080 kg/ha with an average of 2188 kg/ha. The fields have been intensively fall soil sampled on 33.5 and 45.7 m grids for three years. Sunflower appear to leave less residual nitrate-N and chloride than wheat. Phosphorus did not vary much from year to year, but soil P was increasing due to P fertilization. The preplant application of Cl to winter wheat resulted in a higher residual soil Cl in the fall of 1997. After three years, nutrient levels remain related to topography, thus reducing the number of samples needed to determine fertilizer rates. Indications are that sunflower residues may be releasing N to the next crop faster than wheat residue.

FUTURE PLANS: The study will be continued in 1998 with variable rate fertilizer applications. Grain yields will be mapped using a GPS and combine grain yield monitor. Soil sampling will continue. Economic evaluations will be preformed.

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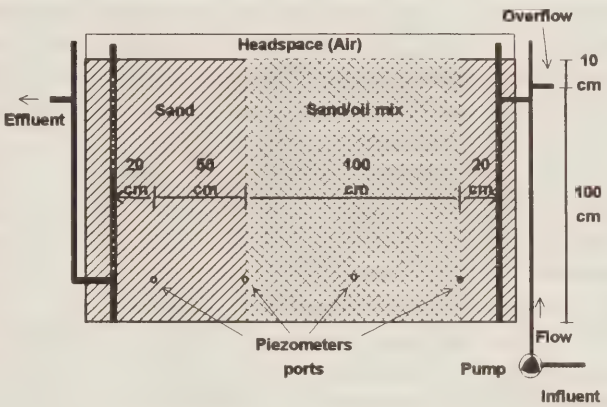
[1]NDSU Extension Service, Fargo, ND
[2]USDA-ARS, Mandan, ND

BIO-DENITRIFICATION OF GROUNDWATER USING INNOCUOUS VEGETABLE OILS

W.J. Hunter

PROBLEM: Nitrate in groundwater is a common water quality problem in sections of the Great Plains and west. Nitrate is relatively nontoxic but is transformed to nitrite following ingestion. In infants, blood oxygen transport can be impaired by nitrite. Innocuous oils can remove nitrate from water. Usually, it is the absence of an electron donor that limits microbial denitrification of groundwater. Oil provides the electron donor. This project is evaluating the potential for using an oil containing denitrifying zone for the *in-situ* removal of nitrate from flowing groundwater. The project is ongoing and the results presented are incomplete and preliminary.

APPROACH: The study used a sand tank as a one-dimensional (85 cm wide) open-top flow model of an aquifer (see schematic). An area near the center of the tank contained sand coated with 1.53 Kg of oil to form a denitrifying zone. A screened influent well was located at one end of the tank and a screened effluent well at the other. Water containing nitrate was supplied to the influent well. Hydraulic conductivity and effluent nitrate, nitrite, pH, suspended solids, dissolved oxygen, chemical oxygen demand (COD), and turbidity were monitored.



Schematic of the sand tank.

FINDINGS: The denitrifying zone was effective at removing nitrate from flowing water for an extended period of time. The nitrate content of the effluent water from the sand tank remained below that of the influent water for about 30 weeks. During this time 39% or 261 g of nitrate-N were removed from 33,356 L of water containing 20 ppm nitrate-N. In the first 10 weeks of operation 93.4% of the nitrate in 6,721 L of water was removed, in the next 10 weeks 44.0 % of the of nitrate was removed from 12,410 L of water, and in the last 10 weeks 9.1% of the nitrate in 14,224 L of water was removed. No accumulations of nitrite were observed. The efficiency of the tank might be improved by a larger sand zone behind the denitrifying zone. COD values averaged 90.0, 7.7 and 3.6 ppm for week 0 to 10, 11 to 20, and 21 to 30, respectively. These high COD values indicate a loss of organic material, either as oil or biomass, from the tank. A larger sand zone behind the denitrifying zone would trap some of this organic material enabling the material to serve as an electron donor for additional denitrification thereby improving the efficiency of the system. This loss of organic material should not be a problem in most *in-situ* situations.

FUTURE PLANS: Future work will be directed at 1) completing the analysis of the laboratory data obtained in CY 97 and 2) preparing the data for publication.

NITRATE LEVELS AND DENITRIFICATION ACTIVITY BENEATH A CATTLE HOLDING PEN

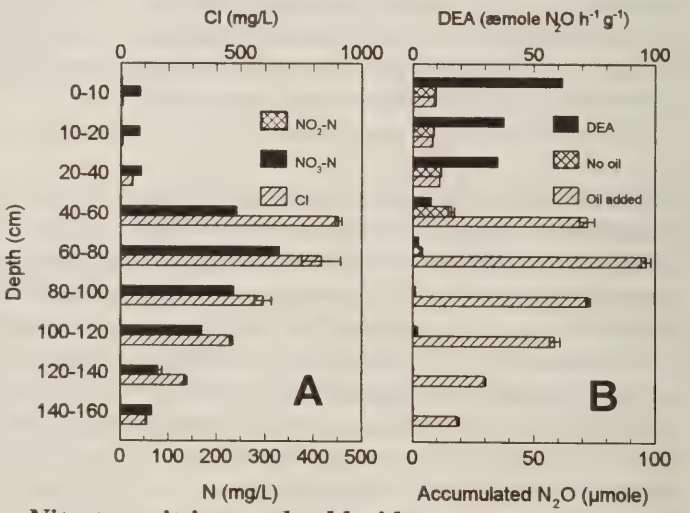
W.J. Hunter

PROBLEM: Contamination of subsurface water by nitrates derived from animal wastes is a common water quality problem in Colorado.

APPROACH: The present study, at a site located in northeastern Colorado about 19 kilometers north of the town of Nunn, evaluated the movement of nitrate from a small cattle pen into the groundwater supplying a well located 41 meters south and downhill from the pens. The site is semiarid and the water table is about 8.5 meters below ground level.

FINDINGS: Water from the well contained 18.0 mg/L nitrate-N. Soil from cores taken from the area between the pen and the well contained between 0.4 and 2.6 mg/L showing that nitrates are not being carried to the well laterally through or over these soils. Soils taken in the pen area contained between 1 and 330 mg/L nitrate-N. The highest nitrate levels occurred deeper (below 40 cm) in the soils. Denitrification activity was highest near the surface (above 40 cm) and above the higher nitrate concentrations. The addition of a term electron donor did not stimulate denitrification in soils from near the surface (above 40 cm) but did stimulate denitrification in deeper soils where nitrate was concentrated. These data show that denitrification activity near the surface, though not limited by electron donor, was not sufficient to prevent nitrate from migrating into deeper soils where denitrification was limited by electron donor availability. Over time nitrate has migrated through the soils beneath the cattle pens and into the groundwater. The data also show the vegetable oil can serve as a term electron donor to stimulate denitrification in these soils.

FUTURE PLANS: Future work will be directed at preparing the data for publication.



Nitrate, nitrite and chloride content (A) and denitrification activities (B) of soils from the corral pens.

PHOSPHATE REQUIREMENTS FOR GROUNDWATER DENITRIFICATION

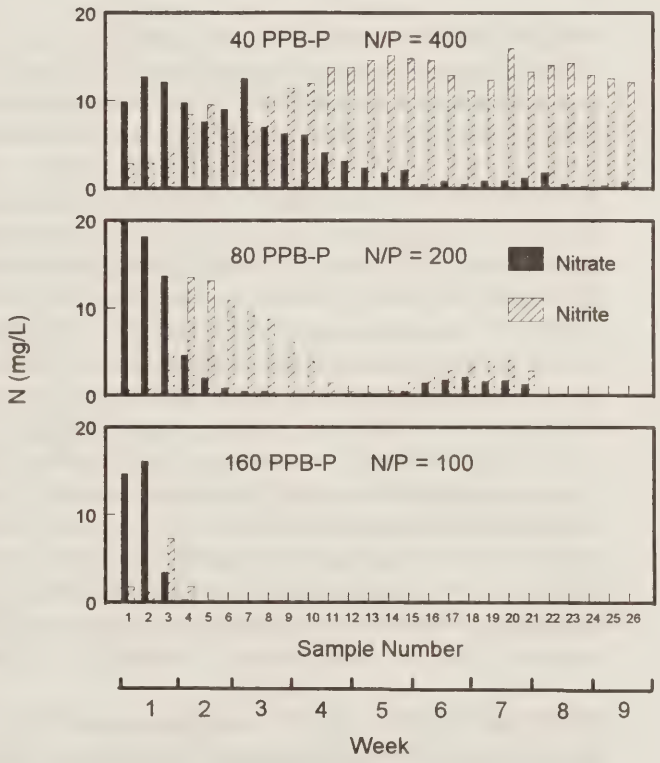
W.J. Hunter

PROBLEM: Nitrate in groundwater is a health concern in Colorado and in many other parts of the U.S. *In-situ* bio-denitrification is perhaps the least expensive approach for nitrate removal. Many studies have shown that it is normally the availability of a term electron donor that limits denitrification and we have shown that water contaminated with nitrate will normally denitrify when pumped though a column containing sand coated with vegetable oils. However, during these studies it was observed that waters from the corral well at the Central Plains Experimental Range (CPER) would not denitrify.

APPROACH: The objective of this study were to determine if phosphate limitations were preventing the denitrification of water from the CPER corral well. This study is ongoing and the data presented are preliminary.

FINDINGS: Analysis showed that water from the CPER corral well contained about 10 ppb phosphate-P. When the phosphate content of the water was increased to 160 ppb-P and the water pumped through a column containing sand coated with oil denitrification occurred rapidly, within 7 days, with only a small accumulation of nitrite (see figure). At 80 ppb-P there was a slight delay in the disappearance of nitrate but a large increase in the amount of nitrite formed. At 40 ppb-P there was a slow reduction of nitrate to nitrite and almost no reduction of nitrite. These results show that the corral well water does not contain enough phosphate to support denitrification and that the reduction of nitrite requires more phosphate than does the reduction of nitrate.

FUTURE PLANS: To determine if solid forms of phosphate, rock phosphate or "Biofos" (a cattle feed supplement), can be used as slow release phosphate sources on the sand columns.



Nitrate and nitrite in effluents of columns supplied with CPER water amended with phosphate.

NO, N_2O, AND CH_4 EXCHANGE IN SEMI-ARID GRASSLAND AND CROPLAND

G.L. Hutchinson and W.X. Yang

PROBLEM: NO, N_2O, and CH_4 are radiatively, chemically, and/or ecologically important trace atmospheric constituents. Microbial processes in soil are a major source of the NO and N_2O and both a source and sink for CH_4, so it is essential to understand the gases' soil-atmosphere exchange and, if needed, to develop mitigation technologies. Short-term exchange rates of the three gases have been measured under a variety of soil and climatic conditions around the world, but longer-term studies of seasonal-to-interannual exchange are conspicuously absent from the literature. Assessing the contribution of the net soil source of each gas to its global atmospheric budget is further confounded by immense temporal and spatial variability in the exchange rates and by the existence of multiple biotic and abiotic soil sources and sinks of the gases, each subject to a different set of controllers.

APPROACH: Our overall goal is to capture field-measured exchange rates of the gases in terms of their basic physical, chemical, and biological controllers. Dependence of the fluxes on these controllers will be characterized in controlled laboratory soil incubation studies and then described using simulation models parameterized by variables observable across different scales.

RESULTS: We completed modification and testing of the commercially available portable luminol-based detector commonly used to measure NO exchange in the field and submitted a description of the modifications for publication. Advantages of the improved detector include faster response time, better accuracy when analyzing wet air samples, and lower operating cost. We used a non-steady-state chamber method to measure soil-atmosphere exchange of NO, N_2O, and CH_4 from semi-arid mixed grass prairie under two different grazing management schemes (continuous heavy grazing and a livestock exclosure). For the six-month period beginning in late May 1997 total emission of NO and N_2O, about 22 and 9 mg N m^{-2}, respectively, was not significantly different between grazing treatments. To improve existing schemes for describing the dependence of NO and N_2O exchange on soil N availability, these data will be compared with periodic measurements of soil NH_4^+, NO_3^-, pH, texture, bulk density, microbial biomass, nitrifier activity, and mineralizable C and N performed on both treatments for a different experimental objective. Both grazing treatments exhibited strong CH_4 sink behavior during the growing season; however, when warm weather in February 1998 initiated spring thaw, the heavily grazed treatment, but not the exclosure, became a CH_4 source.

FUTURE PLANS: Field measurements of NO, N_2O, and CH_4 exchange will continue another year and will be supplemented by measurements from the same soils in a growth chamber experiment conducted for another purpose. Also, in controlled laboratory soil incubation experiments we will use selective microbial inhibitors and independent manipulation of the concentrations and transport rates of gas-phase and solution-phase reactants and products of microbial C and N transformations in soil to characterize the contributions of these and other processes to the exchange rates. Finally, we plan modeling studies to quantify the effect of precipitation/irrigation, soil temperature, and various measures of soil N availability on exchange rates of the three gases.

EVENT-DRIVEN PULSES OF CO_2, NO, AND N_2O EMISSIONS FROM SOIL

G.L. Hutchinson, W.X. Yang and H. Skinner

PROBLEM: A large pulse of CO_2, NO, and N_2O evolution often immediately follows wetting of very dry soil. The pulse is too large to be explained by water's well-defined effects on transport in soil, and its cause remains unclear. Similar pulses sometimes occur following rapid warming of soil previously exposed to near-freezing or subfreezing temperatures, following tillage of partially compacted soil, and possibly following sudden removal of other environmental limitations on microbial growth and metabolism. Emission rates during such an event are 10 to 1000-fold higher than rates preceding or following the pulse, so the quantity of soil C or N lost during its brief duration may exceed the total amount emitted during the much longer period before the soil becomes predisposed to support another emissions pulse in response to the next perturbation.

APPROACH: Both experimental and modeling approaches are being used to examine the relative contributions of biological vs. physical/chemical mechanisms to each emission pulse as a function of the gas species and the pulse driver. A separate combination of field measurements and controlled laboratory soil incubation studies is designed to test the hypothesis that the biological contribution often results from decoupling consecutive reactions mediated by separate microorganisms with different sensitivities to the offending environmental limitation.

RESULTS: We used a non-steady-state chamber method to measure soil-atmosphere exchange of NO, N_2O, and CH_4 from semi-arid mixed grass prairie under two different grazing management schemes (continuous heavy grazing and a livestock exclosure) and two water treatments (natural precipitation and supplemental weekly irrigation to provide a minimum of 2 cm total precipitation per week. The first irrigation was followed by a large NO emission pulse (as much as 78 μg N m^{-2} h^{-1} in both grazing treatments). The intensity of pulses following subsequent irrigations continued to decrease throughout the growing season. A small post irrigation pulse of N_2O often occurred from grazed, but not ungrazed plots. Interestingly, a large pulse of both gases occurred from non-irrigated plots of both grazing treatments following heavy late-July rain on very dry soil; the pulse was smaller from irrigated plots because weekly irrigation precluded developing conditions that support pulsing phenomena. We presented reviews of pulsing's relation to both fine-scale and coarse-scale existing models of gaseous N oxide exchange at separate national and international conferences.

FUTURE PLANS: We will continue the field measurements for another year and add CO_2 to the gases measured. A postdoctoral research associate hired using temporary ARS Global Change Research funds will perform controlled laboratory soil incubation experiments that use selective microbial inhibitors and independent manipulation of the concentrations and transport rates of gas-phase and solution-phase reactants and products of microbial C and N transformations in soil to characterize the contributions of these and other processes to the pulse of CO_2, NO, and N_2O evolution following temperature, wetting, and physical disturbances. Results will be confirmed in the field before incorporation into existing trace gas exchange models.

METHANE, NITROUS OXIDE AND NITRIC OXIDE FLUXES IN THE COLORADO SHORTGRASS STEPPE

A.R. Mosier - Co-Investigators: W.J. Parton [1], D.S. Ojima [1] and D.S. Schimel [2]

PROBLEM: Knowledge of the role of agricultural and rangeland systems on the atmospheric concentrations of trace gases CH_4, N_2O, and NO_x is limited. Since these gases are involved in local and regional atmospheric oxidant concentrations, global atmospheric warming and stratospheric ozone depletion, understanding of the impact of land management and land use change on the soil-atmosphere exchange of these trace gases are needed to understand the changing atmospheric concentrations of these trace gases and to provide research based information to local, regional, national and international policy makers.

APPROACH: In 1990 a program was initiated to measure the soil-atmosphere exchange of CH_4 and N_2O in a variety of systems within the Colorado shortgrass steppe and other regional and more widespread ecosystems. In 1994 quantification of NO_x fluxes was integrated into the program. The program will continue as an integral part of the shortgrass steppe long term ecological research program (NSF/LTER) and earth observation system (NASA/EOS) and data are being incorporated into the data sets being accumulated by the U.S. Trace Gas Network activity that are being used in modeling the local, region and global impact of trace gases.

RESULTS: Land use changes in semiarid grasslands have long-lasting effects. Reversion to near original conditions in plant populations and productivity require more than 50 years following plowing. The impact of more subtle management changes like small annual applications of N fertilizer or changing cattle stocking rates which alters N redistribution caused by grazing and cattle urine deposition were not known. To investigate the long-term effects of N addition to the Colorado shortgrass steppe (SGS) we made weekly, year-round measurements of nitrous oxide (N_2O) and methane (CH_4) from the spring of 1990 through June 1996. Fluxes of NO_x ($NO + NO_2$), N_2O and CH_4 reported here were measured from October 1995 through June 1996. These measurements illustrate that large N applications, from a single dose (45 g N m^{-2}), simulating cattle urine deposition, continued to stimulate N_2O emissions from both sandy loam and clay loam soils 15 y after N application. In sandy loam soils last fertilized 15-y earlier, NO_x emissions averaged 60% greater than from a comparable unfertilized site. The long term impact of these N additions on CH_4 uptake was soil dependent, with CH_4 uptake decreased by N addition only in the coarser textured soils. The immediate impact of small N additions (0.5 to 2 g N m^{-2}) on N_2O, NO_x emissions and CH_4 uptake was observed in field studies made during the summer of 1996. There was little short-term effect of N addition on CH_4 uptake in either sandy loam or clay loam soils. Small N additions did not result in an immediate increase in N_2O emissions from the sandy loam soil, but did significantly increase N_2O flux from the clay loam soil. The reverse soil type- N addition interaction occurred for NO_x emissions where N addition increased NO_x emissions in the coarser textured soil 10 to 20 times those of N_2O.

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SHORTGRASS STEPPE ECOSYSTEM DYNAMICS AND TRACE GAS EXCHANGE UNDER ELEVATED CO_2

A.R. Mosier and J.A. Morgan - Co-Investigators: W.J. Parton[1], D.S. Ojima[1] and D.G. Milchunas[1]

PROBLEM: Atmospheric CO_2 concentrations have been rising in the past few decades at historically unprecedented rates, and are projected to continue rising. No field studies have addressed how elevated CO_2 might impact the shortgrass steppe of the western United States. Based on experiments in other ecosystems, elevated CO_2 is expected to enhance short-term productivity of the grassland but on the long-term CO_2 enrichment may elicit significant soil microbiological responses that will determine the capability of the grassland to respond to CO_2. The CO_2-induced alterations in soil microbial activities will also affect the exchange of CH_4, NO and N_2O within the grassland in unknown ways.

APPROACH: Funding was obtained from the Interagency Terrestrial Ecology and Global Change Initiative to begin research which couples the use of large, open-top chambers for field CO_2 enrichment studies with soil N cycling and trace gas flux measurements. The basic objectives in this research is to determine the impact of doubling CO_2 in the SGS on (1) photosynthesis, productivity, water and N use efficiency, plant water relations, and C and N allocation in above- and below ground parts of two dominant grass species, one C_4 and one C_3 photosynthetic pathway; (2) soil water and N dynamics; (3) fluxes of CO_2, CH_4, NO_x and N_2O; and (4) to incorporate knowledge gained from the studies into simulation models that will allow for realistic extrapolation through time and space of soil moisture, nutrient cycling, plant productivity, and overall ecosystem response.

RESULTS: CO_2 enrichment within the OTC study was initiated in March, 1997. Although most of the season's data analyses are incomplete, we did find that, as expected, above ground plant biomass production was significantly increased with elevated CO_2. C_3 biomass production also increased with elevated CO_2. Weekly small chamber measurements of CH_4, N_2O, NO_x, and CO_2 flux, soil temperature, and surface soil water content indicated that CH_4 consumption was not significantly altered; in contrast to N_2O and dark chamber CO fluxes which were both significantly lower under elevated CO_2 atmosphere

FUTURE PLANS: The CO_2 enrichment study began in the spring of 1997. We anticipate continuing the study for at least 5 years after initial enrichment.

[1]Natural Resource Ecology Lab. and Rangeland Ecosystem Sci., Colorado State Univ.

NORTH AMERICAN TRACE GAS NETWORK (TRAGNET)

A.R. Mosier - Collaborators: D.S. Ojima[1], W.J. Parton[1] and the TRAGNET Steering Committee

PROBLEM: Many trace gas research programs are being conducted in North America. Data is being collected in a wide variety of ecosystems that could be used to answer regional and global questions concerning trace gases. Currently much of the information is fragmented and is not readily accessible by the scientific community as a whole and models developed to describe trace gas fluxes are largely untested because of this fragmentation.

APPROACH: The U.S. Trace Gas Network (TRAGNET) has begun to assemble trace gas field data and models to facilitate intercomparison of data sets and models from around the world. TRAGNET has been funded by the U.S. National Science Foundation to assemble, organize, and synthesize trace gas flux data from a range of ecosystems. TRAGNET is a consortium of research groups with three overall objectives: (1) to document contemporary fluxes of trace gases between regionally important ecosystems and the atmosphere; (2) to determine the factors controlling these fluxes; and (3) improve our ability to predict future fluxes in response to ecosystem and climate change. To accomplish this, TRAGNET is establishing along-term data archive for trace gas fluxes and associated data to facilitate data intercomparison between sites. TRAGNET is also coordinating a series of intercomparisons of trace gas models for these various field sites; this serves both to promote interaction between modeling and measurement groups, and to foster development of robust trace gas flux models.

RESULTS: The U.S. Trace Gas Network (TRAGNET) was initiated to establish database and model analyses to determine general relationships of trace gas exchange between terrestrial ecosystems and the atmosphere across broad environmental gradients. An initial model comparison using data sets from Colorado, Scotland and Germany was conducted and an initial manuscript prepared and submitted for publication. In collaboration with the National Center for Ecological Synthesis and Analysis at Univ. California Santa Barbara a trace gas synthesis and analysis activity was conducted at UC-Santa Barbara. An NCEAS/NREL (Colo. State Univ.) Web site was established and populated with about 30 trace gas flux data sets from around the world from high latitude, tropical, and temperate forests, agricultural and grassland sites from Europe, North and South America. The sites and environmental gradients represented by these sites defined the scope of the synthesis questions that were pursued during the workshop. Results of the NCEAS/TRAGNET collaboration will be presented as a special session of the American Geophysical Union in December, 1998.

FUTURE PLANS: Expansion of the trace gas flux and model data bases is focused to prepare for a second NCEAS/TRAGNET workshop for the analysis and synthesis of trace gas fluxes that is to be held in early 1999. These efforts are being expanded to further development of our capability to predict future fluxes in response to ecosystem and climate change.

[1]Natural Resource Ecology Lab., Colorado State Univ.

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MISSION STATEMENT

Research emphasis is to integrate applied and basic principles to develop improved water, chemical, and alternative weed management systems and irrigation system designs. Improvements are directed toward sustainable, environmentally sound and efficient systems based on soil, water, fertility, energy, and weed ecology principles. This encompasses understanding physical and biological phenomena and developing computer simulation models and precision farming systems to transfer new technologies to producers, consultants, action agencies, industry, and scientists.

TECHNOLOGY TRANSFER

Bausch is a member of a standing ASAE subcommittee to develop measurement and reporting practices for automated agricultural weather stations. Development of these guidelines has broad support and participation by individuals from several professional societies and USDA action agencies.

Bausch is involved in a CRADA with Case Corporation for the field evaluation of a system to manage nitrogen fertilizer applications in corn production.

Bausch and Analytical Spectral Devices, Inc. are jointly interested in investigating the use of hyperspectral canopy reflectance for real-time assessment of plant stress caused by nutrients.

Bausch is involved with Spectrum Technologies, Inc. to evaluate a protoype data logger available for the SPAD chlorophyll meter that interfaces GPS positions with SPAD point measurements.

Buchleiter worked with Underhill International to include irrigation scheduling technology with monitor and control technology in central Kansas.

Buchleiter and Duke provided technical support to several Cooperative Extension agents, Natural Resource Conservation Service field offices, and individual farmers who are doing on-farm irrigation scheduling.

Duke worked with CSU Extension and Colorado Climate Center to make data from the Colorado Ag Meteorologic Network, including crop water use estimates, available over the internet and by direct satellite delivery to farmer subscribers.

Duke served as ARS liason to the USGS National Water Quality Assessment program on the Upper Colorado River.

Duke represented ARS at an NRCS workshop on implementation of BMPs on the Highline Breaks Watershed project in the Arkansas River valley.

Duke served on the Mathematics and Science Advisory Team for Poudre High School.

Duke, Heermann, and Buchleiter provided local arrangements and made technical presentations at the NRCS Western States Irrigation Engineering Workshop held in Fort Collins.

Duke served on a regional USEPA focus group to advise EPA how they can better communicate with the agricultural information user.

Heermann, Buchleiter and Duke are involved in a CRADA with Valmont Industries to extend the capabilities of base station software for monitor and control and to interface and test an independent low-volume chemical application system.

Heermann met with NRCS, Texas Water Development Board and industry representatives for demonstration and training on center pivot system evaluation at Honda, Texas. A followup meeting with NRCS at Bushland, Texas developed new NRCS standards for evaluating center pivot irrigation systems.

Heermann, Blue, Buchleiter, and Duke were recognized with the Government Technology Leadership Award for their contribution to computerized management of irrigation systems.

Heermann was invited and presented a seminar to Poudre High School students on the career opportunities in Agriculture.

Heermann presented the latest in center pivot technology to Sidney, MT area farmers at an Agricultural Conference sponsored by Richland Economic Development, Montana Ambassadors.

The scientists organized and participated in several farmer and researcher oriented meetings to seek input for coordinated, relevant research programs in precision farming and have developed a multidisciplinary team of engineers, agronomists, entomologists, pathologists, economists, statisticians, and weed scientists to take a systems engineering approach to studying the impact of variability on crop yield.

Smith was recognized along with David Goodrich, Carl Unkrich (Tucson), and David Woolhiser (retired) with a Team Award for technology transfer based on the development and application of the KINEROS runoff and erosion simulation model.

Smith participated in an international program on Global Change and Terrestrial Ecosystems to identify and apply erosion simulation models best suited to studying the effect of climate change on agriculture.

Smith provided technical support for a variety of users of the Opus and KINEROS models, and recast the Opus model into a more 'user-friendly' windows95 program.

Wiles advises the Colorado Noxious Weed Management Team on ARS research concerning noxious weeds.

Wiles proposed and organized a workshop, "Weed management decisions: How decisions are made and how scientists can help," for the 1997 annual meeting of the Weed Science Society of America.

SYSTEMS APPROACH FOR MULTIDISCIPLINARY RESEARCH FOR PRECISION FARMING

G.W. Buchleiter, D.F. Heermann, H.R. Duke, W.C. Bausch, R.E. Smith, L. Wiles, D. Westfall[1], P. Westra[1], F. Peairs[1], J. Hoeting[1] and F. Fleming[1]

PROBLEM: Current precision farming (PF) research has focused on correlating spatial variability of a few of the major crop production factors with spatial variability in yield. Many times spatial variabilities of yield in subsequent years are not explained by the prediction model that was developed from previous data. This suggests the prediction model either fails to include all of the major factors affecting yield and/or does not adequately represent all of the major interactions between the various factors. In addition collecting data about some factors using traditional grid sampling approaches is too expensive and/or time consuming to use on commercial farms. Less expensive methods of assessing crop/soil variabilities are needed to improve the economic feasibility of PF.

APPROACH: Eighteen ARS and university researchers developed a PF research project to better understand the various interactions between production factors causing spatial variation in yield under irrigated conditions. To keep data collection efforts manageable and foster cross-disciplinary work within the group, multi-disciplinary data collection efforts are on two commercial fields. The first 2-3 years of the project are devoted primarily to obtaining baseline data, identifying and quantifying the pertinent factors affecting yield, and developing decision aids for PF management. The next 2-3 years will be on-site testing and evaluation of decision support systems for PF, economic feasibility, and assessment of impact on the environment. A project manager coordinates the diverse field data collection efforts using a single labor pool. Because different sampling strategies and analytical methods are used by the various scientific disciplines, close coordination of data collection and analyses across disciplines is essential to reach statistically sound and scientifically based conclusions. Documents describing objectives, sampling densities and analytical procedures for use in the overall analyses were developed.

RESULTS: The multidisciplinary team selected 2 pivots of cooperating producers. Each of the disciplines obtained data for a 76 m x 76 m (250 ft x 250 ft) grid either by sampling or using simulation models that were verified with field data. A web page was created to enable researchers to keep abreast of current field conditions and exchange data. Remote sensing of crop status and electromagnetic conductivity measurements of soil profile were taken as less expensive alternatives to numerous point samples. Yields were measured with yield monitors on the producer's combines. Data were stored in GIS format. Initial data analysis is focusing on a multivariate analysis of the various factors affecting yield.

FUTURE PLANS: As the scales of spatial variability for the various parameters and structure of the data are determined, appropriate alternative sampling and analytical techniques will be explored. Root crops such as sugarbeets or onions will be investigated in the future.

[1] Dept. of Soil and Crop Sci., Bioagric. Sci. & Pest Manage., Bioagric. Sci. & Pest Manage., Statistics, Soil and Crop Sci. at Colorado State University.

PLANT NITROGEN STATUS ESTIMATED FROM CANOPY REFLECTANCE

W.C. Bausch, H.R. Duke, K. Diker and T.M. Bernard

PROBLEM: Water quality issues concerning excessive nitrates in ground and surface water supplies are impacting nitrogen management in many agricultural areas. Small applications of nitrogen as needed by the crop have tremendous potential for reducing nitrate contamination of ground water. Various techniques have been developed to determine plant N status. However, these techniques are laborious, time consuming, and represent point measurements. Remote sensing can sample a plant community rather than a single plant and can rapidly assess the spatial variability that exists in a field. Leaf reflectance at various wavelengths have been correlated to leaf chlorophyll concentration; unfortunately, applications have not been developed for monitoring N status at the plant canopy level.

APPROACH: Canopy reflectance data acquired over irrigated corn plots with six nitrogen levels are being used to correlate with various plant variables (LAI, yield, plant N) and soil nitrogen. Canopy radiance and incoming irradiance are measured simultaneously in the green (G), red (R), and near-infrared (NIR) wavebands using Exotech radiometers positioned perpendicular and at an oblique angle to the crop surface. The radiometers are mounted on a high-clearance tractor. GPS data are taken simultaneously with reflectance measurements to indicate field positions associated with the reflectance data. SPAD chlorophyll meter measurements, leaf area measurements, whole plant sampling for N analysis, canopy reflectance measurements and soil sampling was conducted throughout the corn growing season. Canopy reflectance and associated GPS positions were input into a GIS to map various plant variables and soil N estimated by the N Reflectance Index (NRI). The NRI is defined as the ratio of the NIR/G for a particular field area to the NIR/G for a reference area that is not N deficient.

RESULTS: Plant N status of irrigated corn can be estimated at the V9 growth stage with assurance by using an oblique-view radiometer. However, after tasseling, a nadir view is recommended because the corn tassel overwhelms canopy reflectance at the oblique view. The NRI provides a rapid assessment of N sufficiency that may be superior to the N Sufficiency Index calculated from SPAD data because a plant community is monitored instead of single points on single leaves. Thus, nitrogen fertilizer can be applied "as needed" and "where needed" by the crop. The NRI was successfully used to estimate the spatial distribution of soil nitrogen at the research site through estimates of the plant nitrogen status. GIS mapping of measured and estimated soil nitrogen agreed except in locations where hot spots were measured. Relationships between the NRI and LAI at various corn growth stages were highly correlated (r^2 varied from 0.71 to 0.96) as were relationships between the NRI and corn grain yield (r^2 better than 0.97 for growth stages from V9 to R2).

FUTURE PLANS: Data collection will continue in the 200A block at ARDEC. The east half will be used for studies associated with the Case CRADA and the west half will be used to assess the plant nitrogen status of corn from remote sensing measurements using radiometers. When a threshold of 0.95 is reached as indicated by the NRI, nitrogen will be applied to the deficient plot via the high-clearance tractor applicator (6 plots) and the chemical applicator on the linear move sprinkler (6 plots).

REMOTE SENSING INPUTS FOR PRECISION FARMING UNDER IRRIGATION

W.C. Bausch, T.M. Bernard and K. Diker

PROBLEM: Primary variables that control crop yield in irrigated production sytsems are water, nitrogen, pests or diseases, or other factors that require within-season management. The objective of precision farming is to improve production efficiency by adjusting inputs to conditions existing at specific areas within a given field. Information acquired from point sampling of soil and plant variables is important in understanding field/crop dynamics. However, plant sampling is time consuming and expensive to analyze. Remote sensing, on the other hand, can rapidly provide information to help make site specific management decisions.

APPROACH: A high-clearance tractor instrumented with remote sensing tools and GPS was used to measure canopy reflectance and temperature of corn grown in two commercial center pivot-irrigated fields. Data was taken at weekly intervals (approximately) during the growing season along eight transects through a limited portion of both fields; a data point was acquired every 2 s. The four-channel radiometer and the IR transducer looked perpendicular to the crop surface (nadir view) from a distance of 10 m above ground; both instruments had a 15° field of view. The distance between measurement centers was approximately 3.5 m. A GPS position was associated with the center of the viewed spot. Thirty-five mm color aerial photography was also acquired throughout the growing season to obtain data over the entire field and to correlate with the ground-based spectral measurements. Ground control points were established around each field with GPS and marked for visibility in the images; these points were used to georeference the aerial photographs. SPAD chlorophyll and leaf area measurements were taken near the center of 27 coarse grid locations each time remote sensing data was collected. These measurements where taken within the area of the ground-based remote sensing measurements. Five plants were selected at random for leaf area measurements; 30 plants were selected at random for SPAD measurements.

RESULTS: Maps of leaf area index (LAI) and plant nitrogen status as estimated by the Nitrogen Reflectance Index (NRI) and the Nitrogen Sufficiency Index (NSI) were generated using GIS. LAI varied throughout the measurement area by 20 to 30 %. The NRI calculated from canopy reflectance data measured in the green and near-infrared spectral wavebands showed small isolated areas that were nitrogen deficient in one field; this occurred just prior to tasseling and at the dough (R4) growth stage. The NSI calculated from SPAD data showed similar indications. The aerial photograph at the R4 growth stage showed the nitrogen deficient area as well; however, detailed image analysis of the photographs has not been accomplished at present. Comparisons with yield data have not been conducted; grain yield was depressed somewhat in these areas.

FUTURE PLANS: Canopy reflectance, canopy temperature, leaf area, and SPAD measurements will continue on the two center pivot-irrigated fields to evaluate plant stress effects on yield. A GPS unit will be used with a SPAD meter to locate the field position of individual SPAD measurements for enhanced mapping of the NSI. Color infrared aerial photography will be used in 1998 to obtain near-infrared data to compare with the ground-based near-infrared spectral data. A small wedge (pie-shaped area) of approximately 4 ha in the northeast portion of one field will be established to evaluate plant response to less nitrogen applied through the irrigation system.

DESIGN AND DEVELOPMENT OF SOFTWARE FOR SELF-PROPELLED SPRINKLERS

G.W. Buchleiter and D.F. Heermann

PROBLEM: Growers and researchers both recognize there is significant spatial variability of crop yield within a field. It is hypothesized that production inputs and adverse environmental impacts can be significantly reduced without adverse effects on overall yields using precision farming (PF). Self-propelled sprinklers are a platform capable of providing an integrated package for data collection, analysis, and variable application of water and chemicals to economically deliver PF technology under irrigated conditions. Current limitations include no method for determining field position of linear moves, irrigation scheduling recommendations are compromised because of soil water and water use variabilities, and few irrigation systems are capable of independent variable application of water and chemicals.

APPROACH:. A cooperative research and development agreement (CRADA) exists between USDA-ARS and Valmont Industries, a major center pivot manufacturer, to aid transfer of sprinkler control technology. Nondifferential GPS units are being explored for determining the position of linear move systems. Independent systems for variably applying water and chemicals are installed on a linear move sprinkler system at ARDEC. System uniformity of a pulsed chemical application system under various operating conditions are being simulated with a computer program. User interfaces are under development for linking central microcomputers to multiple self-propelled sprinkler irrigation systems for the control of water and chemicals. A computerized irrigation scheduling program is being revised to account for variations in soil water and water use under a sprinkler system and provide improved irrigation recommendations.

RESULTS: A prototype position calculation module was developed to calculate field position of a linear move sprinkler based on nondifferential GPS and tower motor run time data. The module's microprocessor was programmed in assembly language to request data from and transmit position back to the computerized control panel. Field testing required recalibration of several parameters to improve performance. Unexplained delays in communication with the control panel limited expected accuracy to +/- 3.5 meters when traveling at maximum speed. Additional checks on the input data significantly improved the expected accuracy. A prototype pulse chemical application nozzle was tested extensively in the lab under different pressure and volumetric output conditions to characterize the wetted pattern. Modifications are being made to the computer program to accurately simulate nonsymmetrical patterns at low application rates. The ability to simulate the system uniformity of chemical applications is useful in evaluating alternative nozzle orientations. Work is continuing on a WINDOWS 95 based irrigation scheduling program which better accounts for differences in soil and crop parameters under a single irrigation system.

FUTURE PLANS: Development of prototype programming features will be continued with field testing and evaluation. Software development for automatically translating mapping information about variable rate application to the necessary operational controls on the computerized control panel is planned.

REAL-TIME MANAGEMENT OF IRRIGATION SYSTEMS FOR IRRIGATION WATER QUALITY

H.R. Duke, G.W. Buchleiter, W.C. Bausch, D.F. Heermann and G.E. Cardon[1]

PROBLEM: Variations in climate and pest outbreaks require timely management decisions to minimize water and chemical inputs. Self-propelled sprinklers irrigate about ⅓ the U.S. irrigated acreage and are a unique platform for site specific applications and precise crop management. With appropriate controls and decision making tools, these systems can be managed to account for variation in water, fertilizer, and pesticide needs.

APPROACH: Current research focuses on real-time decisions at the field level rather than on multi-year planning. An integrated system is being developed to: (1) reduce the difficulty of obtaining data, (2) process data quickly, (3) make appropriate recommendations, and (4) implement the producer's decision in a timely manner. Field experiments are used to evaluate the benefit of fertilizer application in response to measured plant needs as effected by the timing of water application. Remote sensing is used to develop rapid assessment of fertility and pests. Three N and two water treatments were imposed on plots under a linear sprinkler irrigation system. Soil water was measured weekly and daily amounts estimated by meteorologic methods. Crop N status was measured weekly with a chlorophyll meter and by remotely sensed reflectance to evaluate spatial and temporal variability. Chlorophyll meter readings were used to trigger weekly N applications to meet crop needs.

RESULTS: Plant chlorophyll was measured with a SPAD meter for real-time control of N application and correlated with remote sensed canopy reflectance. During the 1994-1997 growing seasons, the spoonfed plots required approximately 60 kg/ha less N during 3 of the 4 years, resulting in no statistical difference in grain yields compared to plots fertilized according to the current CSU N fertility algorithm. Spoonfed plots maintained grain yield with nearly 70 kg/ha less total N applied during the growing season. However, plots fertilized preplant in 1997 with 60 kg/ha less N than recommended also yielded the same as those fertilized at recommended rate, suggesting that the preplant recommendations are too high, rather than the spoonfeeding more efficient. Unaccounted for N increased sharply as water application reached 130% of ET, indicating either denitrification or leaching. Although not statistically significant, the efficiency of N use to produce grain was consistently higher with the spoonfed plots (52 kg grain/kg N) than conventional fertilization (42 kg grain/kg N). Software developed allows control patterns to be manually inputted to generate commands to the sprinkler system for implementation of VRT.

FUTURE PLANS: The water and N study under the linear move linear sprinkler is complete. Procedures developed to incorporate remotely sensed data of crop N status directly into control algorithms will be used for real time scheduling of N applications. These spoon-fed applications will be implemented with the high clearance tractor and with the sprinkler mounted chemical application system. Effectiveness of application algorithms and implementation will be determined by comparison of grain yield with that of plots receiving conventional fertilization.

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SPATIALLY AND TEMPORALLY VARIED WATER & CHEMICAL APPLICATION

H.R. Duke, G.W. Buchleiter, D.F. Heermann, W.C. Bausch and J.A. Chapman[1]

PROBLEM: Precision agriculture technology is being driven by demand, with little scientific basis. Decisions made prior to planting or last cultivation do not account for seasonal variation. Soil properties, fertility, weeds, insects, and other pests vary both spatially and temporally within a single field. Management that takes into account spatial and temporal variation has the potential of reducing costs and environmental degradation by applying water and chemicals only when and where needed. Center pivot and linear move irrigation systems are used on 1/3 of the U.S. irrigated acreage and provide a mechanism to transport both the water application and chemical application systems. With appropriate controls, these irrigation systems can also apply water and chemicals in different amounts in different parts of the field as needed.

APPROACH: Plots have been established at CSU's ARDEC under a linear-move sprinkler system approach to apply fertilizer as needed. Spatial variation of fertilizer nitrogen need is measured throughout the season. Sprinkler remote controls have been modified to determine field position and apply chemicals to segments of the field as needed. Low cost devices have been developed and are being evaluated for mounting on the sprinkler system to apply variable rates of chemicals. The seasonal distribution of both irrigation and precipitation is being measured under two commercial center pivot sprinkler irrigation systems as part of a major precision farming project to evaluate the potential for improving uniformity of irrigation.

RESULTS: Sprinkler controls and software have been modified to determine the field position and to implement variable water and chemical application under the linear move sprinkler. Water application has been reliably controlled by pulsing sprinkler heads. A pulsed chemical application system has been developed and tested. Spatial distribution of irrigation and rainfall water application was determined during the 1997 season on two commercial fields. Although the uniformity coefficient was relatively high for irrigation (.86 on each sprinkler), approximately 10" excess water above crop requirements was applied on each.

FUTURE PLANS: Needed fertilizer nitrogen, as determined by remote sensing, will be applied using the pivot mounted chemical application system on 6 plots and using the high clearance tractor on an additional six plots under the linear move sprinkler at ARDEC. Distribution of precipitation and irrigation will be measured under the two center pivots for a second season. In subsequent seasons, the sprinkler packages will be redesigned and we will attempt to influence the farmers' water and fertility practices to apply both water and nutrients in just the amounts and at the time needed.

[1] Valmont Industries, Inc., Valley, NE.

ON-SITE INTERACTIVE MODEL FOR IRRIGATION PEAK ELECTRICAL LOAD MANAGEMENT

D.F. Heermann, L.E. Stetson[1] and G.W. Buchleiter

PROBLEM: Irrigation pumping is concentrated during a three- to five- month period during the summer for much of the pump-irrigated areas of the U.S. Electric powered pumping increases the peak demands of the electric utilities serving these irrigation loads, requiring costly investments in generation and transmission facilities that are severely underutilized during the non-peak use periods. Since revenues from irrigation pumping are a significant part of the annual revenue for some utilities and do contribute to the economies of communities in irrigated areas, it is desirable to keep power affordable so irrigation remains profitable. Many retail power suppliers have begun irrigation load management programs that reduce their peak demands to reduce or avoid increases in demand charges from their wholesale supplier. Water management research has shown that crop water consumption can be calculated and the results used to schedule irrigation systems for optimum water application. This irrigation scheduling can result in more irrigation systems operating simultaneously which could increase peak power demands. The need is to develop the load control technology that allows power suppliers to generate the needed revenue while providing electricity at a cost that allows sustainable and profitable operations.

APPROACH: The existing EPRI model for predicting irrigation demands of a retail power supplier will be integrated with existing ARS programs for predicting crop water needs to develop modules for an on-site interactive program to predict daily electric loads caused by irrigation. The perceived needs of irrigators will be compared with actual water needs of the crops to determine the potential reductions in demand. Time series models which using a base model for the year can be updated as current data becomes available is under investigation. Asymmetric loss functions are being investigated because our main concern is in predicting the peaks of the electrical demand.

RESULTS: The initial analysis was to develop correlations between the daily peak demands and the climatic data. The primary correlation was determined between the rainfall and sharp drop in peak demands from one day to the next. As interesting as this maybe it does not provide the needed estimate of the future peak daily demands. The relationship between peak demands and crop water use are not significant. It may be that the irrigators do not schedule irrigations based on crop ET but base their decision on perception and historical experience for scheduling irrigations. The current approach is to model the time series of demand data for use in estimating the future short term demands. Scaled Legendre Polynomials were fit to multiple years. The resulting model appears to have similar estimating parameters for several years and is being explored further. A model is being developed to describe the base line curves of the demand data. The next step will be to determine procedures for estimating the deviations from the base line to forecast the future peak demands.

FUTURE PLANS: The search for a robust time series model that can predict the short term peak electric demands will continue as discussed in the approach and results above.

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EVALUATION MODEL FOR PERFORMANCE OF CENTER PIVOT SYSTEMS

D.F. Heermann, H.R. Duke and T. Spofford[1]

PROBLEM: Center pivot irrigation systems now irrigate approximately 25% of the total irrigated area in the United States. Based on center pivot manufacturers' sales, the percentage of the irrigated area under center pivots will increase as farmers convert to sprinklers to reduce labor requirements and to irrigate land not suitable to surface methods. Improved sprinkler uniformity is needed to reduce over irrigation and the resulting negative environmental impact on water quality. The Natural Resource Conservation Service (NRCS) is expending considerable effort in collecting field data for evaluating and recommending improvements to sprinkler systems. A computer simulation model developed for research on center pivots, appears to offer potential for decreasing the effort required to evaluate these systems by calculating applied depths based on the sprinkler hydraulics rather than analyzing catch can data. This model can be used to evaluate the system uniformity as well as test alternative system modifications before they are made. A user friendly interface is needed to enable non-technical personnel to enter the necessary data and interpret the output correctly.

APPROACH: A user friendly model will be developed for use by NRCS technicians and engineers. The model will provide for the entry of field catch can data as is now often collected for use in determining the irrigation uniformity. A pump test and inventory of the sprinkler heads, spacing, and pipe sizes of the system can serve as input to the model and provide an alternative way of evaluating the system. The adoption of low pressure systems requires an increased number of catch cans for an appropriate evaluation. This also makes it important to study the effect of start-stop of the towers which can reduce the uniformity. The first effort will be to investigate the errors introduced in the evaluation process when assuming the system is a continuous move without the start-stop of towers. The current integration requires extensive computation and simplifying techniques will be studied.

RESULTS: A user friendly model for use in Windows95 on personal computers has been written and is being Beta tested by the NRCS. Low capacity systems are difficult to design for uniform application when they require small nozzles which are easily plugged with foreign matter. A system was designed and simulation evaluation completed that used pulsing of larger nozzle sprinklers to reduce the instantaneous flow required for low capacity systems. A graphical user interface to the evaluation model is being developed for non expert users. The user supplied data required for the simulation includes: pipe sizes, pump curve, sprinkler head spacing, sprinkler type, nozzle sizes, pattern shape, discharge coefficients, pressure regulators, and desired operating speeds.

FUTURE PLANS: Different techniques for integrating the application depth of the moving system is being studied. The intent is to add a test phase to the evaluation that provides the irrigator specific recommendations for making modifications and for use in scheduling irrigations. The model will be expanded to estimate the uniformity of application using pulsing heads with tower start-stop conditions.

[1] USDA-Natural Resources Conservation Service, Portland, OR.

EVALUATING FARMER DEVELOPED MANAGEMENT ZONES FOR PRECISION FARMING

K.L. Fleming[1], D.G. Westfall[1], D.F. Heermann and W.C. Bausch

PROBLEM: Developing accurate application maps for variable rate (VRT) fertilizer application is critical in implementing precision farming technology. Intensive grid soil sampling is traditionally used to develop application maps, however the cost and labor intensity associated with grid sampling suggests other approaches may be more feasible. Determining fertility management zones may provide a more economical method of developing VRT application maps. Research is needed to determine the minimum information required to develop accurate management zone maps.

APPROACH: It's well documented that variation in soil fertility across landscape positions affect crop yield. Soil type, moisture, and organic matter affect soil color and can easily be captured on either color or black and white film. Scientists know that the experiences of farmers have been extremely important in the development of agriculture as we know it today. Producers have knowledge of which parts of a field produce good yield and which areas are low in production. It is logical that nutrient needs are different in these areas. This allows identification of different management zones in a field based upon farmers knowledge of past production history. Based on these relationships a study is proposed to determine if farmer developed management zone maps based on landscape position, aerial photographs of soil color, and past management experience can be effective in developing VRT application maps. A field study was initiated in 1997 on two center pivot irrigated fields in northeast Colorado to assess the technical and economic feasibility of precision farming. Data from these locations will be used to evaluate farmer developed management zones. Aerial photographs will be used as an initial template in developing management zones. The producer will then draw vector lines to establish the individual management zones (high, medium, and low productivity areas) based on landscape position, soil color, and management experience on the field. This management zone map will be correlated with maps of fertility, texture, conductivity, topography, yield and remote sensing data. Our hypothesis is that farmer developed management zones will provide an effective and economical method of creating variable rate application maps.

RESULTS: Initial work indicates a positive correlation of management zones with organic matter, nitrate, potassium, zinc and crop yield. Variation of these parameters within management zones is less than the variation over the whole field.

FUTURE PLANS: To further access farmer developed management zones for VRT a field scale trial will be initiated at three locations in northeast Colorado in 1998. Five treatments will be applied, uniform rates of 0, 75, 150 lbs/ac, VRT based on management zones delineated by the producer, and VRT based on grid sampling. Spatial statistical techniques will be used to evaluate the data and make appropriate conclusions.

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MEASURING AND CHARACTERIZING SPATIALLY DISTRIBUTED SOIL HYDRAULIC PROPERTIES

R.E. Smith, G. W. Buchleiter and H. Farahani

PROBLEM: Soil water movement and transport can be simulated if the local soil hydraulic properties are known. These properties vary considerable across a field, even for visually uniform soils, and this variation needs to be characterized to make intelligent management decisions. Current field techniques for measuring soil hydraulic properties are much too time-consuming to allow enough samples to be taken over a field unit to adequately characterize spatial variabilities. There is little data available describing the spatial stochastic structure of soil variations. Much simpler and more rapid measurement methods are needed for this purpose. With such tools the spatial characteristics of soil properties can be studied and better strategies for managing water in precision agriculture can be developed.

APPROACH: A small single-ring sorptimeter was developed as a means to rapidly sample local soil surface sorptivity. This parameter is the best single representation of local surface soil intake capacity. Sorptimeter tests were conducted this year on two center pivot circles in eastern Colorado. Samples were taken at sampling scales covering almost two orders of magnitude, from 5 to 250 ft. spacing. The data are intended to provide insight into scales of surface soil variability, and to provide insight into strategies for sampling in precision agriculture.

RESULTS: Analysis of the sorptimeter data is ongoing, but preliminary results clearly indicate that variability is dominated by small scale random variations. There is very little spatial structure in the surface sorptivity of these soils under current farming conditions. Variograms at all scales show a strong nugget effect; that is, there is no distance below which the surface sorptivities are spatially correlated. The distributions from clusters of samples at different locations representing different soil series do show mean values that have a statistically significance difference, but the difference is nevertheless small with respect to the variance. Thus one can observe that a subarea of the field cannot be well represented by taking a single sample, as is often done in soil mapping.

FUTURE PLANS: Spatial sampling will be continued this year, with concentrations primarily on clusters at small sampling distances, with coverage of parts of the fields that represent expected differences in soil types. Some additional study of the spatial statistics of characteristics better representing a greater depth of the soil should also be undertaken.

SURFACE WATER REDISTRIBUTION UNDER MOVING SPRINKLERS

R.E. Smith, D.F. Heermann, P. Luz[1] and H. Farahani

PROBLEM: Sprinkler irrigation systems, especially high volume, low energy types, have the potential for applying water at a higher rate than the local infiltration capacity of the soil. Center pivot systems are designed to apply the same water depth along the lateral, so the rate and thus the potential for ponding varies with distance from the pivot. Additional complications are introduced by variations in topography and soil type or condition. Runoff at any location can move elsewhere and adversely affect the plant water availability and crop yield. Study of this problem requires the integration of spatial soil and surface slope information with simulation of time and space variation of application rates. This information may then be used with physically realistic and dynamic simulation of infiltration and movement of any surface water produced. There is no existing simulation tool with these capabilities, and such tools are potentially useful in design and analysis of irrigation systems.

APPROACH: GIS spatial software will be used to develop a tool that will integrate spatial information with dynamic simulation for water movement over a field. Selecting the GIS platform is made difficult by the unusual nature of this type of GIS application. New ESRI products appear to be better suited to use with the dynamic simulation required. GIS software is inherently better at representing spatial data, and the objective is to take advantage of that ability in the spatial simulation using large amounts of data layers, so that most simulation results will be graphic rather than generating massive output files.

RESULTS: Loss of a support scientist has severely limited progress on this project this year. The simulation "engine" for moving surface water under the competing dynamics of sprinkling rate and infiltration has been improved, including greater windows 95 compatibility. A prototype framework for moving sprinkler input map in GIS has been made, but the full system has yet to be constructed. The continuing evolution of ESRI products and transitioning to a windowsNT environment has also impeded progress.

FUTURE PLANS: Addition of new staff with GIS experience and expertise will accelerate work in this area.

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WATER, NUTRIENT AND CHEMICAL MANAGEMENT WITH SPATIAL VARIABILITY

R.E. Smith, D.F. Heermann, G.W. Buchleiter and D. Santos[1]

PROBLEM: The onset of interest in site-based management or precision agriculture has highlighted the lack of robust models for, or understanding of, the effects of nutrients, soils, weather variables, and crop properties on yield, seepage, leaching, and other important variables that are of economic and environmental concern. The spatial variability measured in yield has not been easily related to the spatial variations measured in many of the variable cited above. Moreover, there is a need for better understanding of the local relationships between applied water, runoff, water use, and seepage of water below the root zone. As more is learned about the system that encompasses the plant and soil, there is potential for collecting more appropriate data for site specific agriculture, as well as making much better decisions for site-specific management.

APPROACH: An existing model, Opus, for the local crop/water/soil/nutrient system will be evaluated and refined on a site basis using data collected as part of several precision agriculture studies. Some studies will emphasize nutrient transport, others will focus on water movement, crop growth, or pesticide fate. If the model proves able to simulate site observations, it may be applied with the spatially variable data that are being collected as part of the WMU precision agriculture study. The model should be able to aid in evaluating the sensitivity of various management options in terms of either yield, efficiency, or environmental objectives. To date, Opus simulations have been made at several points on two large center pivots.

RESULTS: Transport and crop/water relations simulated by Opus have been evaluated in several different studies. Also, the Opus model has been improved and put into a Windows95 format for ease of use. Santos has shown in plot studies in Portugal that Opus can reasonably simulate the vertical transport and use of nitrogen fertilizers under flood irrigation. Opus' pesticide fate and transport capability was studied by experimental comparisons in studies in Georgia and Virginia. The Opus simulation of crop water ET and soil evaporation on the two center pivots showed good agreement in terms of local crop yields and ET relationships. The creation of a graphic user interface (GUI) for Opus has also reached the testing stage.

FUTURE PLANS: In future studies, sensors will be used to measure local soil moisture in the root zone and compared to the simulations from Opus. A GUI for use in creating data input files for Opus should be completed next year. Also, the model can be further modified to make it more useful in spatial applications, so that GIS format data can be accessed in spatial modeling applications.

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DEVELOPMENT AND APPLICATION OF DYNAMIC RUNOFF AND EROSION MODELS

R.E. Smith, D.C. Goodrich[1] and J.N. Quinton[2]

PROBLEM: Whenever there is water running on the soil surface, erosion may occur, whether the water is an irrigation event or runoff from a natural rainfall. In addition, when runoff is produced by either excess rainfall or sprinkler irrigation, the splash energy will exacerbate the erosion, resulting in loss of topsoil and nutrients, and often pollution of receiving waters. This is a complex and difficult process to predict or to simulate, and almost all currently used models simplify and lump the process, or use regression techniques to make long-term estimates. To improve our understanding and predictive ability, we need better understanding of the erosion process in its full dynamic, spatially variable condition.

APPROACH: Our approach is to consider erosion as a transport process intimately linked with the dynamics of flowing surface water and the energy of the rain or sprinkler input. Simulation of runoff depends heavily on the quality of our predictions of infiltration. The convective transport of soil material is linked with expressions for local erosion and deposition rates, and an expression for the splash detachment of falling water drops. Existing data for the transport capability of shallow surface flows can be mathematically represented in our models. The processes of erosion and deposition can be treated as continuous concurrent processes with hydraulic energy thresholds. Knowledge needs to be developed in several areas, including the interrelations of transportability when several particle sizes are present, the initiation and stochastic relations involved in the formation of rills, and the transient character of crusts formed during rainstorms, which can help to reduce erodibility.

RESULTS: This year we have applied our dynamic simulation models to data sets from a test catchment in Holland, with associated learning in several model areas. It appears that the current assumptions regarding the normal range of splash erosion parameters may be heavily underestimating the amount of splash-caused detachment. In addition, further evidence was gained that smaller particle sizes are not as significant in erosion losses due to the binding of smaller particles in aggregates. Model improvements have continued based on these experiments, including transition to windows-based operations. The KINEROS model's next version (KINEROS2) is essentially complete, with work remaining on completing the documentation. This includes the description of runoff for areas with spatial heterogeneity, and description of runoff for two-layer soil profiles.

FUTURE PLANS: Hopefully time from other projects will be found to finish the formal documentation of KINEROS2. A new cooperative project (MWISED), which includes studies of transient conditions within the storm and the development processes for rills, begins this year.

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[2] Silsoe College, Cranfield, Silsoe, England.

SITE-SPECIFIC WEED MANAGEMENT: SAMPLING AND ASSESSMENT

L.J. Wiles, D.H. Barlin, D.Y. Wyse-Pester[1] and P. Westra[1]

PROBLEM: Weed populations often have patchy distributions within fields. This suggests the potential for site-specific weed management to reduce herbicide use, cut input costs and improve environmental quality. That potential must be explored. We need to develop strategies to sample a weed population and create the map for identifying the optimal site-specific management. Also, we need to determine if the benefits of site-specific management will exceed the cost of the additional sampling and management.

APPROACH: Simulation experiments will be done to identify cost-effective scouting strategies for preemergence and postemergence site-specific weed management and to assess the costs and benefits of this management strategy. These experiments require extensive data on the distribution of weed and weed seed bank populations in fields. Weed and weed seed bank populations were sampled in two center pivot-irrigated, commercial corn fields (130 ac and 175 ac) in eastern Colorado. Samples were collected on a 250 ft square grid across the entire field and on 25 ft square grids covering 500 sq ft at three locations in each field. Seed bank samples (2462 cores) were collected after planting and stored for later elutriation and analysis. Weeds were counted and identified by species in 5 ft of row at 1390 locations before and following postemergence management and just prior to harvest.

RESULTS: Populations differed between fields, but the composition and distribution of weed and weed seed bank populations within a field were similar. Each field had one species with plants and seeds detected throughout the field. Other species had more limited and patchy distributions with some species detected only near the edge of the field. A population in one field strongly reflected past management: seed and plant populations were uniformly more dense in one half of the field than the other. Populations changed in density and distribution during the season. This change varied with management and species characteristics. The pattern of change in one population indicates possible herbicide resistance. This study is unique in that whole fields were sampled. Most studies involve sampling just a portion of a field. Compared to those studies, our whole-field results suggest more challenges in detecting patches and highlight the need to direct sampling based on knowledge of past management.

FUTURE PLANS: The sampling of 1997 will be repeated in 1998 and data from both years will be used to in the simulation experiments. In addition, we will try to map the spatial distribution of herbicide resistance within one population. Weed seeds collected in 1997 will be grown to seedlings and screened for herbicide resistance. Also, plants will be screened in the field in 1998.

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DESCRIBING WEED POPULATIONS: DECISION MAKERS USING MODELS

L.J. Wiles, S.R. Canner[1] and D.B. Bosley[2]

PROBLEM: Weed management decision models as are being developed to help growers and crop consultants select optimal weed management strategies. Some of these models, such as the General Weed Management model (GWM) and the GPFARM weed module, require users to supply estimates of weed density by species for a field. Density estimates for portions of a field will likely be needed for site-specific weed management decision models. The value of the information generated by these decision models will vary with the accuracy of the density estimates. However, few crop consultants or growers count to estimate weed density. If such weed management decision models are to be used, we need to identify methods to obtain accurate information about weed density from users.

APPROACH: Twelve crop consultants and eight farmers from eastern Colorado were individually interviewed to learn how they assess and describe weed populations in order to make a management decision. The design of the interview was based on earlier group interviews with crop consultants and growers and included general discussion of weed management, scouting, and terms used to describe weed populations. Also, the crop consultants and farmers were asked to assign density ratings to pictures of weed populations with different densities and to choose one of their fields and describe its weed population.

RESULTS: Only one participant counted weeds while scouting. All participants used terms such as "light, moderate, heavy" to describe the population of a weed species, however, this appeared to be an estimate of weed pressure, the potential damage from a population, rather than weed density. Density is just one of many factors contributing to pressure. Other factors include species, predicted additional emergence, weed size and location of the weed relative to the crop row. Participants had difficulty discussing density and assigning specific densities to ratings such as "low" or "high." However, many liked the idea of using pictures to communicate about density. These results suggest that part of the decision process is redundant in that both users and models are accounting for influence of important factors such as species and later emergence.

FUTURE PLANS: Potential solutions for the redundancy include developing scouting plans that estimate weed density with no or minimal counting, designing model interfaces to translate the user's estimate of weed pressure into a density estimate, and restructuring models to use weed pressure rather than density in the decision process. In 1998, we will investigate presence/absence scouting plans and the use of video of weed populations to help users provide density estimates for decision models.

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A NEW APPROACH FOR MODELING MULTI-YEAR WEED POPULATION DYNAMICS

L.J. Wiles, S.R. Canner[1], C.M. Dunan[1] and R.H. Erskine[1]

PROBLEM: Weed management is a critical factor in decisions about crop rotation and tillage practices, and can be a large component of the production costs and environmental risks of crop production. The Great Plains Systems Research Unit is developing a decision support system (GPFARM) which simulates economic and environmental outcomes of medium and long term farm and ranch management plans. Potential users indicated that GPFARM should include a module that predicts the impact of weed and crop management strategies on crop yield and weed population dynamics. Existing weed models were not suitable for GPFARM. Weed population dynamics modeling techniques have typically been based on detailed models which are difficult and expensive to parameterize. Most weed models are single-year tactical decision support systems, while most models which simulate weed population dynamics are only parameterized for a single weed and a single crop. The GPFARM weed module needs to be parameterized for at least 15 weeds and 4 crops, using only existing data.

APPROACH: The first version of the GPFARM weed module included a very simple population dynamics method which could be parameterized from expert opinion or readily available literature sources. In 1997, a new approach was implemented which preserved the basic simplicity of the original model, but added density dependence of weed reproduction and greater interpretability of the parameters. This was made possible by the development of a new equation for describing dependence of weed seed production on weed and crop density. This new equation can be parameterized using information from readily available data which describe the impact of weed density on crop yield. This density dependence factor is integrated into a simple population change model which is generally equivalent to most detailed weed population dynamics models, yet requires fewer parameters. Like the original GPFARM weed module, the parameters of this module are easy to estimate from expert opinion or literature sources. The model has been parameterized for 15 weeds and 4 crops. We have begun testing the model with data from western Nebraska, including a study of summer annual weeds in irrigated corn and a study of winter annual weeds in dryland crop rotations.

RESULTS: The model performed reasonably well on both data sets, but tended to over predict weed densities in treatments where there was substantial herbicide use. This suggests that some adjustments in how herbicide efficacy is modeled may be in order. The model appears to be fairly effective in simulating the impacts of cultural management on weed population trends.

FUTURE PLANS: Model parameters will be refined and testing will continue. Sensitivity analysis and more detailed statistical analysis of test results will allow us to focus on model weaknesses. The model structure will be enhanced to allow for better responsiveness to tillage system and irrigation.

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ARCHIVING DATA AND MULTIVARIATE ANALYSIS FOR PRECISION FARMING

D.F. Heermann, G.W. Buchleiter, M. Brodahl, K.L. Fleming, J.A. Hoeting[1] and M.J. Paulson[1]

PROBLEM: A multi-disciplinary research project is being conducted for at least 5 years, to evaluate the economic feasibility and environmental consequences of precision farming (PF) under irrigated conditions. Eighteen researchers are collecting the data they feel are necessary to assess the impact of various factors on yield from two fields on commercial farms. Initially the large data sets obtained by these researchers must be archived in standardized formats that can be used in multivariate analyses to identify and quantify factors affecting yield. These data from different sources and in different formats must be well documented so future analyses and interpretations are based on the correct assumptions and analytic procedures.

APPROACH: Baseline data are to be collected for the first 2 years to assess the spatial and temporal variabilities of the various factors that can effect yield. Each researcher provides data on a 250 ft x 250 ft grid spacing either from field sampling or by calculating values from a simulation program or model calibrated from sparser field measurements. These data are stored in a GIS format where each parameter defined by an individual researcher is considered a layer of information. Metadata, which is a standardized format describing the data collection and processing procedures of each parameter, are attached to each data layer for future reference and documenting limitations of the data. A central repository controlled by a single person, is established to archive and control access to the data provided by the various researchers. Several approaches to multivariate analysis will be investigated to identify and quantify the major factors affecting yield.

RESULTS: Maps of various factors have been created for both fields. GPS was used to map topography, electromagnetic conductivity, and locate sampling points for the grid. Soil nutrients, soil sorptivity, weeds, and insects were sampled on a 250 ft grid spacing. Maps showing variabilities of water application, crop water use, and deep percolation were developed using a combination of computer simulation programs and field sampling. Yield maps were created from yield data collected by combines equipped with grain monitors. These data sets are being archived in a GIS format (ARCView?). Mean and standard deviations of the data sets are being calculated for use in a statistical multivariate analysis.

FUTURE PLANS: Other analytical approaches for interpreting the factors affecting yield will be investigated based on the characteristics of the data collected. Modeling capabilities of GIS software packages will be investigated. Decision support systems based on these analytic approaches will be developed and linked to variable rate technologies in the field.

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OTHER RESEARCH UNITS

IN THE CO/WY COUNCIL

THE ARTHROPOD-BORNE ANIMAL DISEASES RESEARCH LABORATORY

Laramie, Wyoming

The Arthropod-Borne Animal Diseases Research Laboratory (ABADRL) is a special purpose laboratory for research on arthropod-borne virus diseases of domestic animals. The purpose of the research is to protect U.S. animals from domestic, exotic and emerging arthropod-borne animal pathogens and provide information to enhance U.S. competitiveness in the international trade of livestock and livestock germplasm.

ARTHROPOD-BORNE DISEASES OF ANIMALS AND U.S. AGRICULTURE: Arthropods, such as biting insects, ticks and mites, transmit a variety of disease causing pathogens to ruminant livestock. In the U.S. these pathogens cause a variety of diseases such as bluetongue disease, epizootic hemorrhagic disease, equine encephalitides, and anaplasmosis. Foreign arthropod-borne pathogens pose great danger. The entry of an exotic or emerging pathogen could devastate U.S. livestock industries. Among the foreign pathogens that pose great danger are exotic forms of bluetongue virus, vesicular stomatitis virus, Rift Valley fever virus, heartwater, African horse sickness, African swine fever, iberaki and akabane viruses.
The international community through the Office of International Epizootics (OIE) seeks to reduce the threat of the spread of animal pathogens. OIE's most dangerous animal pathogens are those causing the 15 diseases on OIE List A. Five of these are arthropod-borne, and two (bluetongue and vesicular stomatitis) have been found in the U.S. The presence of List A diseases cause direct economic losses as a result of the disease in animals, and significantly reduces trade from non-tariff trade barriers imposed to try to reduce the spread of the disease. The economic consequences of the List A diseases can be catastrophic. Animal health regulations to reduce the spread of these diseases must be based on sound scientific information to be economically efficient and effective. The ABADRL provides this information.

ABADRL RESEARCH: The bluetongue and vesicular stomatitis viruses are the most serious of the arthropod borne pathogens for the U.S. livestock industry. Both are List A diseases. Bluetongue is endemic in the U.S. and results in disease and non-tariff trade restrictions costing the U.S. over $100 millions annually. Although considered a foreign pathogen, outbreaks of vesicular stomatitis in the U.S. have occurred in 1982, 1985, 1995 and 1997. The costs in lost trade, restrictions on animal movement have been many millions of dollars.

The ABADRL provides the following types of information:

- The role of insects in transmission and pathogenesis.
- The interaction of insects and pathogens in causing clinical disease in animals.
- New diagnostic procedures to detect viruses in domestic and foreign animals.
- The effectiveness of novel prevention and control strategies.
- Knowledge to predict the risk to the U.S. from exotic and emerging pathogens.
- Analyses of the scientific basis for animal health regulations for these and other arthropod-borne animal pathogens.

FACILITIES: ABADRL is a biosafety level B/L-3AG laboratory, for work solely devoted to insect vectors, insect borne animal pathogens and for studies which involve infected domestic

animals. The facilities allow the ABADRL to conduct work on exotic arboviruses, classification 3* in safe biocontainment. Containment laboratories are designed with negative pressure, HEPA filtered air and sewage sterilization treatment.

PERSONNEL: The ABADRL has 6 full-time scientists with the Ph.D., DVM or both degrees. The research is multi-disciplinary and requires a interactive effort that involves the expertise of the entire staff. Members of the ABADRL provide expertise for work with insects, viruses and host animals. The ABADRL multi-disciplinary effort is unique in addressing arthropod borne pathogens. As a result the ABADRL research is widely known and used by scientists working with human pathogens.

KEY POINTS:

- Arthropod-borne animal pathogens cause great economic losses to U.S. agriculture.
- Increased international trade increases the risk to the U.S. for the entry of dangerous foreign or new arthropod-borne animal pathogens.
- List A diseases are the most dangerous.
- Bluetongue disease is on List A and is endemic in a large region of the U.S.
- Vesicular stomatitis is on List A and there have been recent outbreaks in the U.S.
- Research on these and other potential diseases is essential to protect U.S. agriculture.
- Research is essential to prevent the occurrence of domestic and foreign animal diseases.
- Research is essential to control disease outbreaks using efficient environmentally friendly control strategies.
- Research on these diseases is a national priority and requires a un-biased federal effort to avoid potential regional conflicts of interest.
- Research is essential to protect U.S. agriculture while maintaining U.S. international markets.
- This research requires biocontainment facilities.
- This research requires a multi-disciplinary, integrated and targeted research effort.
- The ABADRL provides efficient facilities, a multi-disciplinary trained staff, and a targeted research program for addressing current and emerging arthropod-borne animal diseases into the 21st century.

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NATIONAL SEED STORAGE LABORATORY

FT. Collins, CO

NATIONAL SEED STORAGE LABORATORY: The mission of the National Seed Storage Laboratory is to preserve the base collection of the U.S. National Plant Germplasm System and to conduct research to develop new and improved technologies for the preservation of seed and other propagules of plant genetic resources.

SEED VIABILITY AND STORAGE RESEARCH UNIT: The mission of the Seed Viability and Storage Research Unit is to effectively document and preserve viable seed of diverse plant germplasm in long-term storage, to periodically monitor viability, to evaluate new procedures for determining quality of accessions during storage and regeneration, and to distribute germplasm to National Repositories and for quarantine grow-outs. Specific objectives are:

- To preserve the base collection of plant germplasm for the National Plant Germplasm System.
- To determine initial quality and to periodically monitor viability of plant germplasm placed into storage at the National Seed Storage Laboratory.
- To continuously maintain and update the National Seed Storage Laboratory database on GRIN.
- To develop practical methods for evaluating seed quality of species which do not have established viability testing procedures and to develop methods for identifying cultivar duplication.
- To establish routine protocol for the storage of clonal germplasm.

PLANT GERMPLASM PRESERVATION RESEARCH UNIT: The mission of the Plant Germplasm Preservation Research Unit is to insure that the United States has a safe and secure supply of plant germplasm for current and future generations by conducting research which will lead to the development of new and improved technologies for the long-term preservation of all forms of plant germplasm. Specific objectives are to:

- Improve cooperation and coordination among germplasm curators to identify priorities for long-term germplasm preservation.
- Develop methods to preserve plant propagules of species and accessions not currently in the base collection.
- Develop and improve technologies for evaluating viability, vigor, genetic integrity, and potential longevity of preserved germplasm.
- Evaluate conventional and cryogenic storage protocols and develop strategies to improve cost efficiency.
- Conduct pilot studies to evaluate protocols for long-term preservation of plant propagules in order to transfer technology to germplasm curators, seed companies, and other customers.

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SUGARBEET RESEARCH UNIT

Ft. Collins, CO

MISSION STATEMENT: The mission of Sugarbeet Research is to: 1) develop, adapt and apply new knowledge and biological technologies to understand and modify host-pathogen relations that affect disease resistance, pathogenesis, and epidemiology in sugarbeet and other crops, taking advantage of the unique environmental conditions present in Fort Collins, Colorado; and 2) produce new information and techniques to identify and create plant genotypes that exhibit high levels of disease and stress tolerance together with superior agronomic qualities.

RESEARCH PROGRAM: The Sugarbeet Research Unit (SRU) develops new knowledge and technologies for (1) sugarbeet genetic resistance to disease, (2) host-pathogen interactions of fungal diseases, (3) nematode and fungal biological control, (4) germplasm enhancement & improved sugarbeet quality. Objectives of these efforts are reduced pesticide usage and more efficient production of beets and sugar.

The SRU is the major site of research in the U.S. for development of new knowledge and nonchemical control and technology of fungal diseases of sugarbeet, particularly for Cercospora leaf spot and Rhizoctonia root rot. Research focuses on the cause and effect of pathogenesis and host response to develop host resistance and biological control. Research results from this project have broad application to other crop/pathogen systems. The unit's research projects involve relatively expensive field testing and validation.

Genotypes resistant to Rhizoctonia root rot, Cercospora leaf spot, and the curly top virus have been developed; however, techniques are needed for rapidly introgressing these genes into parents of commercial hybrids having characters for high root and sucrose yield, as well as resistance to other sugarbeet diseases. Additionally, biological controls of root rot and the sugarbeet cyst nematode are urgently needed. These goals require a research program capable of bridging traditional breeding methods to state of the art molecular technologies.

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